FEDERAL LAND MANAGERS' AIR QUALITY RELATED VALUES WORKGROUP (FLAG)

PHASE I REPORT
(December 2000)

U.S. FOREST SERVICE – AIR QUALITY PROGRAM
NATIONAL PARK SERVICE – AIR RESOURCES DIVISION
U.S. FISH AND WILDLIFE SERVICE – AIR QUALITY BRANCH

Table of Contents

APPENDIXES

A. EXECUTIVE SUMMARY

The Federal Land Managers' Air Quality Related Values Work Group (FLAG) was formed to develop a more consistent approach for the Federal Land Managers (FLMs) to evaluate air pollution effects on their resources. Of particular importance is the New Source Review (NSR) program, especially in the review of Prevention of Significant Deterioration (PSD) of air quality permit applications. The goals of FLAG have been to provide consistent policies and processes both for identifying air quality related values (AQRVs) and for evaluating the effects of air pollution on AQRVs, primarily those in Federal Class I air quality areas, but in some instances, in Class II areas. Federal Class I areas are defined in the Clean Air Act as national parks over 6,000 acres and wilderness areas and memorial parks over 5,000 acres, established as of 1977. All other FLM areas are designated Class II. Maps of Federal Class I areas are provided in Appendix E. Lists of Class I Area contacts are provided in Appendix F.

FLAG members include representatives from the three FLMs that administer the nation's Federal Class I areas: the U.S. Department of Agriculture Forest Service (USDA/FS), the National Park Service (NPS), and the U.S. Fish and Wildlife Service (FWS). (Subsequently in this report, these three agencies collectively will be referred to as "FLMs." Class I and Class II air quality areas are called "FLM areas" in this report.) Appendix G contains a list of FLAG Participants.

This report describes the work accomplished in Phase I of the FLAG effort. That work includes identifying policies and processes common to the FLMs (herein called "commonalities") and developing new policies and processes using readily available information. This report provides State permitting authorities and potential permit applicants a consistent and predictable process for assessing the impacts of new and existing sources on AQRVs, including a process to identify those AQRVs and potential adverse impacts. The report also discusses non-new source review considerations and managing emissions in Federal areas. In Phase II, FLAG will address unresolved issues including those that will require research and the collection of new data.

This *FLAG Phase I Report* consolidates the results of the FLAG Visibility, Ozone, and Deposition subgroups. The chapters prepared by these subgroups contain issue-specific technical and policy analyses, recommendations for evaluating AQRVs, and guidelines for completing and evaluating NSR permit applications. These recommendations and guidelines are intended for use by the FLMs, permitting authorities, NSR permit applicants, and other interested parties. The report includes background information on the roles and responsibilities of the FLMs under the NSR program.

This document includes guidelines for completing and evaluating NSR applications that may affect FLM areas. It does not provide a universal formula that would, in all situations, allow one to determine whether or not a source of air pollution does, or would, cause or contribute to an adverse impact. That determination remains a project-specific management decision, the responsibility for which remains with the FLM, as delegated by Congress. The FLM's assessment of whether or not an adverse impact would occur is based on the sensitivity of the AQRVs at the particular FLM area under consideration.

To provide information for the FLM's assessment of adverse impacts on AQRVs, the permit applicant should identify the potential impacts of the source on all applicable AQRVs of that area. An FLM may ask that an applicant address any or all of the areas of concern. The primary areas of concern to the FLMs with respect to air pollution emissions are visibility impairment, ozone effects on vegetation, and effects of pollutant deposition on soils and surface waters.

The *FLAG Phase I Report* also describes the FLAG effort–including the FLAG approach, organization, and plans for future FLAG work. Appendix A of the report contains a glossary of technical terms, abbreviations, and acronyms used in the report along with associated definitions. Appendix H provides a list of all references cited in the FLAG report.

The key recommendations developed by the Visibility, Ozone, and Deposition subgroups are summarized below. However, for all three subject matter areas, FLAG recommends that the permit applicant consult with the appropriate regulatory agency and with the FLM for the affected area(s) for confirmation of preferred procedures. This consultation should take place in the early stages of the permit application process.

1. RECOMMENDATIONS FOR EVALUATING VISIBILITY IMPACTS

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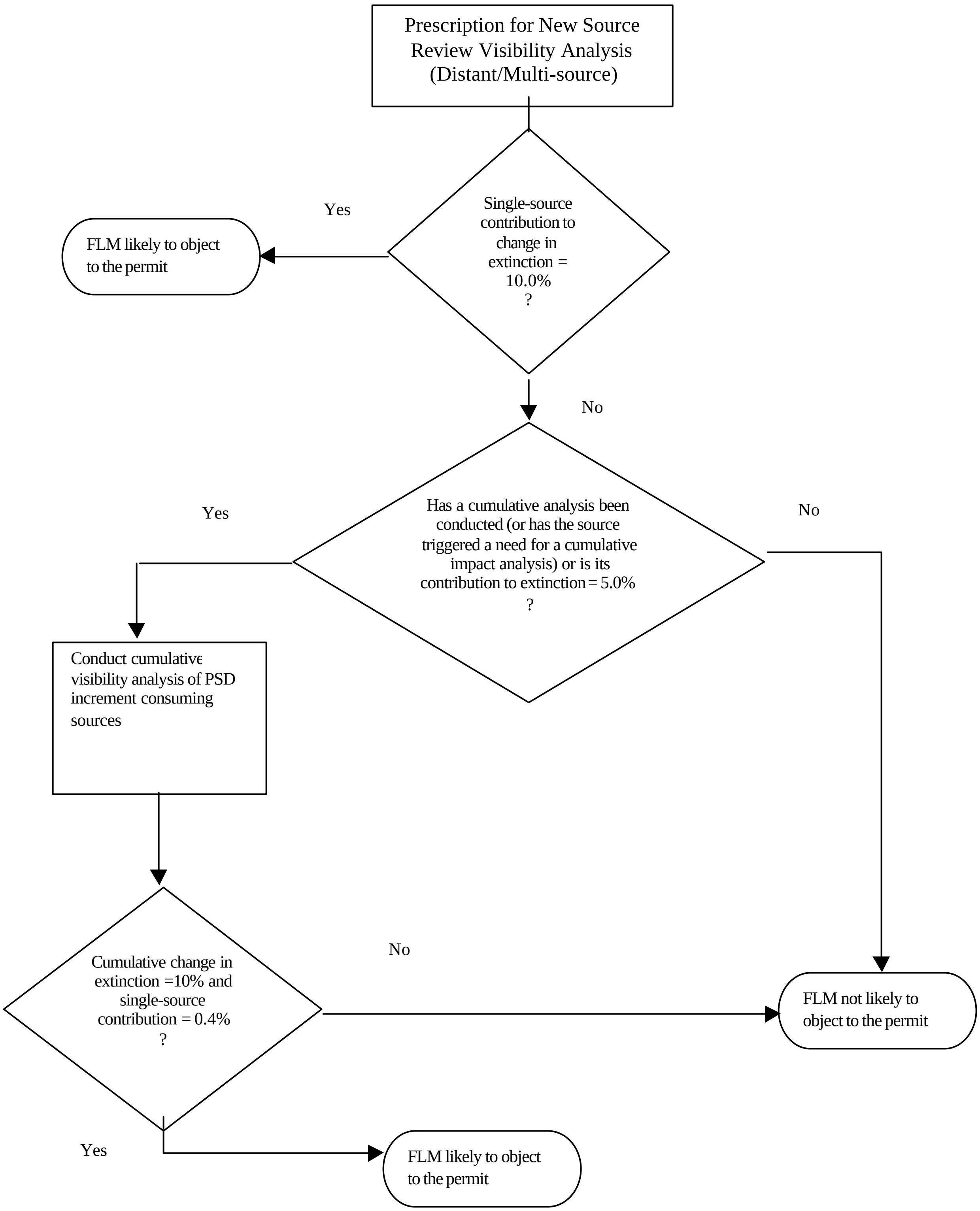
Calculate the change in extinction due to the source being analyzed, compare these changes with the reference conditions, and compare these results with the thresholds given in Section D.2.c.

If necessary, calculate the cumulative change in extinction due to new source growth.

This prescription is portrayed schematically in Figure V-1.

Figure V-1. Prescription for visibility assessment for distant/multi-source applications (source greater than or equal to 50 km from the Class I area)



2. RECOMMENDATIONS FOR EVALUATING OZONE IMPACTS

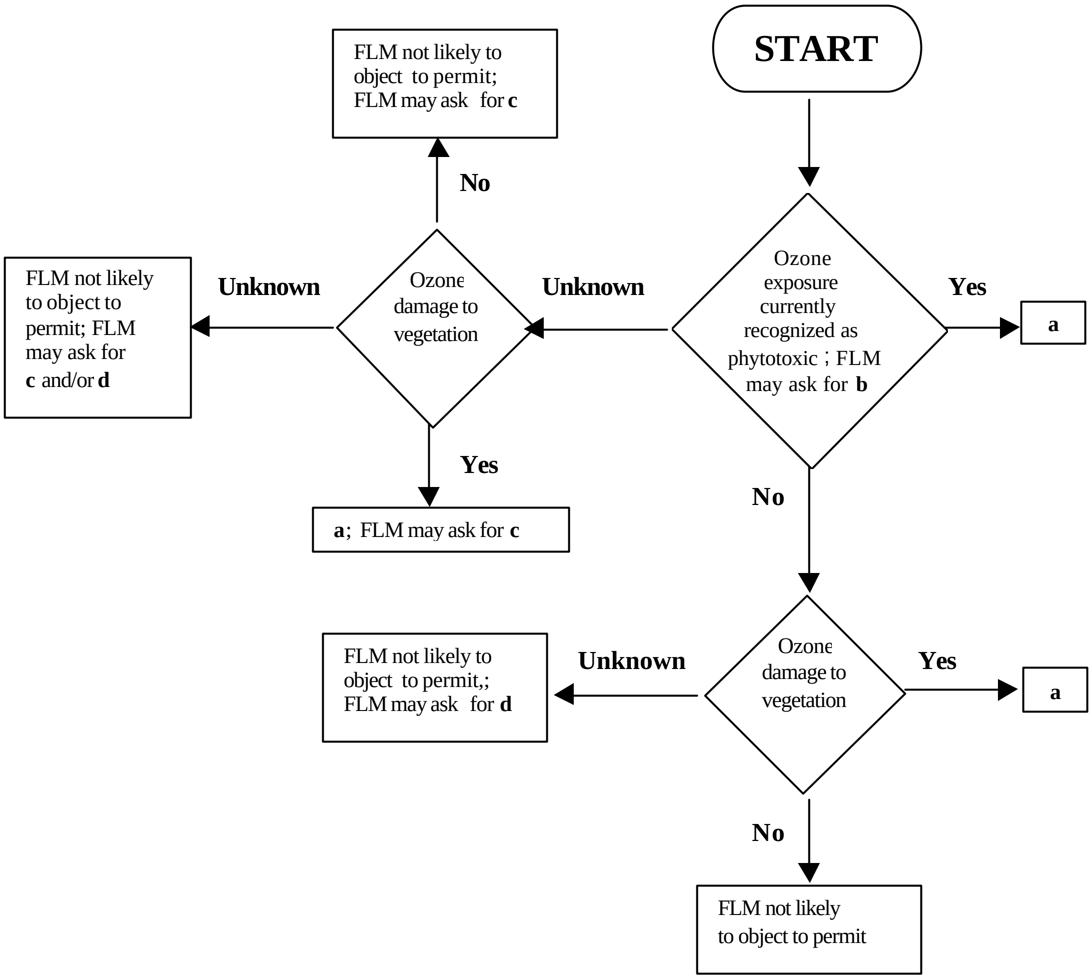
- FLAG agrees with the EPA contention that single source-receptor modeling for ozone is not feasible at this time. FLM actions or specific requests on a permit application will be based on the existing air pollution situation at the area they manage. These conditions include (1) whether or not actual ozone damage has occurred in the area, and (2) whether or not ozone exposure levels occurring in the area are high enough to cause damage to vegetation (*i.e.*, phytotoxic O_3 exposures). Figure O-1 shows the various responses an FLM would have to a permit application. (Note: the term "Ozone exposure currently recognized as phytotoxic" is determined based on data from exposure response studies and ambient ozone levels at the site. The FLM may ask the applicant to calculate the ozone exposure values if these data are not already available. "Ozone damage to vegetation" is determined from field observations at the impacted site.)

- Oxidant stipple necrosis on plant foliage and ozone-induced senescence infer adverse physiological or ecological effects, and are considered to be damage if they are determined to have a negative impact on aesthetic value.

- The W126 ozone metric is recommended to describe ozone exposure, based on a 24-hour, seasonal (April through October) period of measurement. The number of hours in this period of time greater than or equal to 100 ppb (N100) will also be determined, in recognition of the importance of peak concentrations in plant response.

- NO_x and VOC are of concern because they are precursors of ozone. Current information indicates most FLM areas are NO_x limited. Until we determine the VOC or NO_x status of each area, we will focus on control of NO_x emission sources.

Figure O-1. FLM response to potential ozone effects from new emissions source.



Items referenced in Figure O-1:

a. The FLM may recommend one or more of the following:
   - That the proposed source use stricter than BACT controls (*e.g.*, Lowest Achievable Emission Rate [LAER]).
   - That the proposed source obtain NO_x emission offsets that will benefit the potentially affected FLM area (as demonstrated by dispersion modeling).
   - That the permitting authority (*i.e.*, state or EPA) conduct regional modeling to identify sources that are contributing significantly to ozone-associated impacts in the FLM area, and that the permitting authority then undertake actions necessary to reduce emissions from those sources (*e.g.*, SIP revision).
b. The applicant calculate the ozone exposure for vegetation (using W126 and N100 metrics) for the affected FLM area(s) where such information is not already available.
c. The permitting authority or applicant fund post-construction ambient ozone monitoring in or near the FLM area.
d. The applicant conduct or fund post-construction ozone effects surveys in the FLM area and/or exposure/response effects research.

3. RECOMMENDATIONS FOR EVALUATING DEPOSITION IMPACTS

The permit applicant should consult with the appropriate regulatory agency and FLM for the affected area(s) to determine if a deposition impact analysis should be done. If an analysis is advised, the permit applicant should obtain available information on Class I AQRVs, critical loads, and concern thresholds from the FLM. In addition, the applicant should refer to the "Recommendations and Guidance for Evaluating Potential Effects from Proposed Increases in Deposition to an FLM Area" section of the Deposition Chapter (Section D.4.f). The following steps summarize that guidance.

- Estimate the current deposition rate to the FLM area. A list of monitoring sites providing data to characterize deposition in FLM areas is included in the Deposition Chapter (Table D-2).

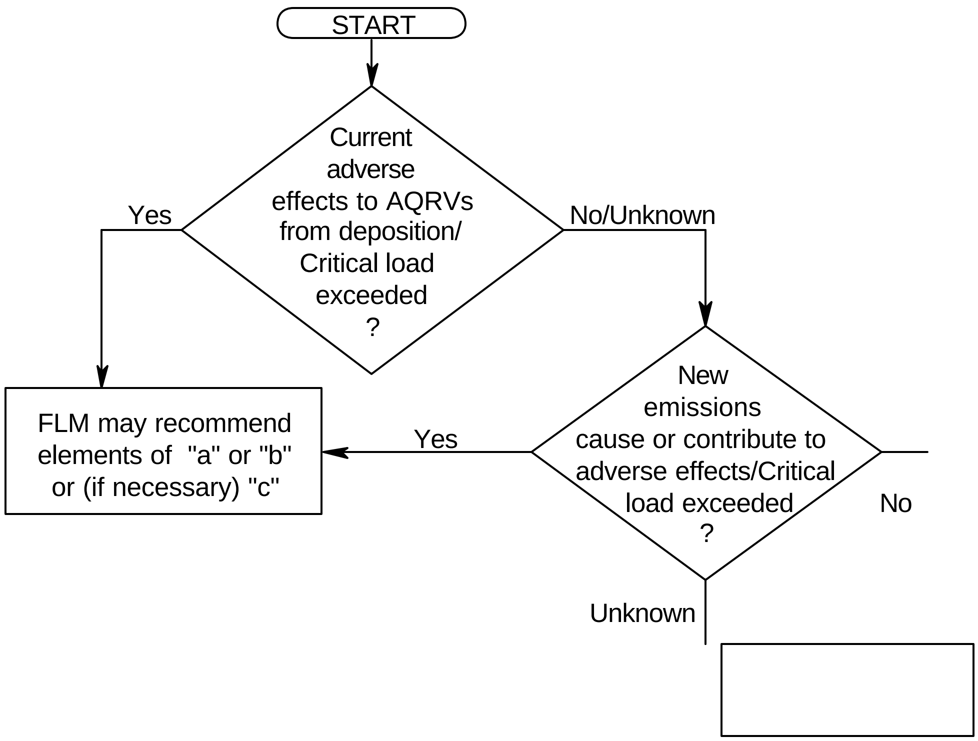
- Estimate the future deposition rate by adding the existing rate, the new emissions' contribution to deposition, and the contribution of sources permitted but not yet operating. Modeling of new and permitted but not yet operating emissions' contribution to deposition should be conducted following IWAQM recommendations.

- Compare the future deposition rate with the recommended screening criteria (*e.g.,* critical load, concern threshold, or screening level value) for the affected FLM area. A list of documents summarizing these screening criteria, where available, can be found in Appendix H. Information for USDA/FS Class I areas is also available at:

  http://www.fs.fed.us/r6/aq/natarm.

  A website with NPS and FWS Class I area information is currently under development.

- In consultation with the FLM, use the following flowchart (Figure D-1) to determine whether mitigation is recommended.



a. The applicant should use one or more of the following:
  - Stricter (than BACT) controls (e.g., Lowest Achievable Emission Rate [LAER]).
  - Emission offsets located in an area that, considering geographic and meteorological factors, will benefit the impacted wilderness or park, as demostrated by modeling.
  - Regional modeling to identify sources contributing significantly to deposition adverse effects; SIP revision to reduce emissions contributing to adverse effects.
  (See text for discussion of mitigation options.)

b. Deposition and deposition effects monitoring/research in the FLM area.

c. Denial of permit.

B. BACKGROUND

1. HISTORY

The Clean Air Act Amendments of 1977 give Federal Land Managers (FLMs) an "affirmative responsibility" to protect the natural and cultural resources of Class I areas from the adverse impacts of air pollution. (See Appendix B. "LEGAL FRAMEWORK FOR MANAGING AIR QUALITY AND AIR QUALITY EFFECTS ON FEDERAL LANDS.") FLM responsibilities include the review of air quality permit applications from proposed new or modified major pollution sources near these Class I areas. If, in its permit review, an FLM demonstrates that emissions from a proposed source will cause or contribute to adverse impacts on the air quality related values (AQRVs) of a Class I area, the permitting authority, typically the State, can deny the permit.

Individually, FLMs have developed different approaches to identifying AQRVs and defining adverse impacts on AQRVs in Class I areas. For example, in 1988, the U.S. Department of Agriculture Forest Service (USDA/FS) conducted a national screening process to identify the AQRVs for each of its Class I areas. Using this national process as a starting point, each USDA/FS region refined the screening parameters and identified sensitive AQRVs for many Class I areas. However, this resulted in differences in the approaches and levels used by USDA/FS regions. The U.S. Department of the Interior National Park Service (NPS) and the U.S. Fish and Wildlife Service (FWS) have adopted a case-by-case approach to permit review, considering the most recent information available for each area. NPS and FWS have not completed lists of sensitive AQRVs nor defined adverse impact levels for all of their Class I areas.

a. FLAG Approach

Air resource managers from the USDA/FS, NPS, and FWS recognized the need for a more consistent approach among their agencies with respect to their efforts to protect AQRVs. In April 1997, an interagency workgroup was formed whose objective was "to achieve greater consistency in the procedures each agency uses in identifying and evaluating AQRVs." The workgroup named itself the Federal Land Managers' Air Quality Related Values Work Group, or FLAG. Although FLAG membership comprises air resource managers and subject matter experts from the three agencies, representatives from the U.S. Environmental Protection Agency (EPA), U.S. Geological Survey, and State air agencies have also participated in FLAG efforts.

FLAG participants have collaborated to:

- define sensitive AQRVs,
- identify the critical loads (or pollutant levels) that would protect an area and identify the criteria that define adverse impacts, and
- standardize the methods and procedures for conducting AQRV analyses.

To accomplish its objective, FLAG started with (and will continue to build on) the procedures, terms, definitions, and screening levels common to the three agencies. Many such "commonalities" were identified early in the FLAG planning sessions. (See section B.4. "COMMONALITIES AMONG FEDERAL LAND MANAGERS.")

FLAG's "Action Plan" stipulates a phased approach. Phase I addressed issues that could be resolved without research or the collection of new data. Phase II will address the more complex and unresolved issues from Phase I that may require additional data collection. (See section E. "FUTURE FLAG WORK.")

The FLAG effort focuses on the effects of the air pollutants that could affect the health of resources in Class I areas, primarily pollutants such as ozone, particulate matter, nitrogen dioxide, sulfur dioxide, nitrates, and sulfates. In Phase I, FLAG concentrated on four issues: (1) terrestrial effects of ozone; (2) aquatic and terrestrial effects of wet and dry pollutant deposition; (3) visibility impairment; and (4) process and policy issues. Four subgroups, one for each of these issues, were formed and charged with developing a set of recommendations for consistent policies and processes.

In Phase I, FLAG findings and technical recommendations underwent scientific peer review, as well as review by agency decisionmakers such as Class I area Park Superintendents, Refuge Managers, and Forest Supervisors; Regional Foresters; and the Assistant Secretary for Fish and Wildlife and Parks. (Note: USDA/FS has designated the FLM as the Regional Foresters and, in some cases, Forest Supervisors. However, the Assistant Secretary for Fish and Wildlife and Parks holds FLM responsibilities for NPS and FWS.) FLAG products have also undergone public review and comment. [A "notice of availability" of the draft FLAG report was published in the *Federal Register*, and the FLMs conducted a public meeting to discuss the draft FLAG report and provided a 90-day public comment period.]

b. FLAG Organization

In addition to the four subgroups (policy, deposition, ozone, and visibility), the FLAG organization included Leadership and Coordinating Committees and a Project Manager. The Leadership Committee, which includes the air quality program chiefs from the three FLM agencies, was responsible for providing direction to the workgroup and the resources necessary for FLAG to accomplish its objective. The Coordinating Committee, which also includes representatives from each agency, was responsible for communications within the workgroup, including coordination among the agencies and subgroups. The FLAG Project Manager coordinated FLAG activities, served as a single point-of-contact for the subgroups, and performed other administrative functions.

2. OVERVIEW OF RESOURCE ISSUES

Research conducted on Federal lands by FLMs and others has characterized natural resource effects associated with air pollution, and has helped identify those particular resources that are vulnerable to pollution. This effort does not address the impacts from air pollution on cultural resources. Documented effects include impairment of visibility, injury and reduced growth of vegetation, and acidification and fertilization of soils and surface waters. Air pollution effects on resources have been identified in a number of FLM areas; a few examples are provided below. It is important to note that similar, or even more serious, air pollution effects may be occurring on all Federal lands, but FLMs have not had the financial resources to perform the inventorying, monitoring, and/or research necessary to document such effects.

a. Visibility

Visitors to national parks and wildernesses list the ability to view unobscured scenic vistas as a significant part of a satisfying experience. Unfortunately, visibility impairment has been documented in most Class I areas with visibility monitoring. Most visibility impairment is in the form of regional haze. The greatest visibility impairment due to regional haze occurs in the eastern United States and in southern California, while the least impairment occurs in the Colorado Plateau and Nevada Great Basin areas, and in Alaska. Sulfate is primarily responsible for visibility impairment in the eastern United States (*e.g.,* Shenandoah National Park in Virginia); in southern California the majority of visibility impairment is attributable to nitrates (*e.g.,* San Gorgonio Wilderness); in the Northern Rocky Mountains and Pacific Northwest, impairment is primarily due to organics (*e.g.,* Glacier National Park in Montana); and in the intermountain West, sulfate, organics and elemental carbon are the main cause of impairment (*e.g.,* Grand Canyon National Park in Arizona) (Sisler *et al.,* 1993).

Visibility impairment on Federal lands can also result from plume intrusion and has been documented in Mount Zirkel Wilderness, Moosehorn National Wildlife Refuge, and Grand Canyon National Park.

b. Vegetation

While several components of air pollution (*e.g.,* sulfur dioxide, nitrogen dioxide, and peroxyacyl nitrates) can affect vegetation, ozone is generally acknowledged as the air pollutant causing the greatest amount of injury and damage to vegetation. The most common visible effects are stipple (dark colored lesions on leaves resulting from pigmentation of injured cells), fleck (collapse of a few cells in isolated areas of the upper layers of the leaf, resulting in tiny light-colored lesions), mottle (degeneration of the chlorophyll in certain areas of the leaf giving the leaf a blotchy appearance), necrosis (death of tissue), and in extreme cases, mortality. Aside from visible injury, ozone exposure can result in less obvious physiological impairment such as decreased growth or altered carbon allocation.

Ozone fumigation experiments have identified a number of plant species that are sensitive to ozone. For example, fumigations were conducted in Great Smoky Mountains National Park (Tennessee and North Carolina) from 1987 to 1992. On the basis of foliar injury, thirty species were rated as sensitive to ozone levels that occurred in the park. The species with foliar injury included black cherry (*Prunus serotina*) and American sycamore (*Platanus occidentalis*). Additional observations and physiological measurements indicated elevated ozone reduced leaf, root, and total dry weights, and increased the severity of leaf stipple and premature leaf abscission in these two species (Neufeld and Renfro, 1993a,b). Field observations have documented foliar injury of these species in other eastern United States areas such as Brigantine Wilderness (New Jersey) and Cape Romain Wilderness (South Carolina).

Ponderosa pine (*Pinus ponderosa*) and Jeffrey pine (*Pinus jeffreyi*) are recognized as good candidates for ozone-injury surveys in the western United States, based on their documented sensitivity. For example, these species were examined for ozone injury in national parks and national forests in the California Sierra Nevada from 1991 to 1995. The sites surveyed included Lassen Volcanic, Yosemite, and Sequoia/Kings Canyon National Parks and the Tahoe, Eldorado, Stanislaus, Sierra, and Sequoia National Forests. Foliar injury attributable to ozone was found at all areas, and the extent of injury generally increased in a southward direction along the Sierra Nevada (Miller *et al.*, 1995).

c. Soils and Surface Waters

Acidity in rain, snow, cloudwater, and dry deposition can affect soil fertility and nutrient cycling processes in watersheds and can result in acidification of lakes and streams with low buffering capacity. Deposition of sulfate to sensitive watersheds results in leaching of base cations, soil acidification, and surface-water acidification. In some soils, sulfate adsorption results in "delayed" acidification of surface waters. Deposition of excess nitrogen species (nitrate and ammonium) to both terrestrial and aquatic systems can result in acidifying streams, lakes, and soils. There is also evidence that nitrogen deposition can cause shifts in phytoplankton composition in lakes in which biological activity is limited by nitrogen availability, *i.e.*, increased nitrogen deposition can cause phytoplankton species that use nitrogen more efficiently to eventually dominate the lake.

Water chemistry surveys and on-going monitoring show that many high elevation lakes on Federal lands in the Sierra Nevada, Cascades, and Rocky Mountains are sensitive to acid deposition. In general, these lakes are on bedrock that provides them with very little buffering capacity. Some of these lakes, for example, Loch Vale in Rocky Mountain National Park (Colorado) experience episodic acidification during Spring snowmelt (Baron and Campbell, 1997).

Through funding provided by the Southern Appalachian Mountains Initiative, Herlihy *et al.* (1996) compiled information on surface water sensitivity of streams in nine of the eleven Class I areas in the Southern Appalachians. The nine Class I areas were grouped according to geology, physiography, and stream chemistry, then the groupings were ranked in terms of effects. Class I areas in the West Virginia Plateau (Otter Creek and Dolly Sods Wildernesses) had the highest percentage of acidic stream length and lowest pH values. Class I areas in the Northern and Southern Blue Ridge (*e.g.*, Shenandoah National Park in Virginia and Joyce Kilmer/Slickrock Wilderness in North Carolina) had a lower percentage of acidic stream length, however, streams with low buffering capacity were common. The Alabama Plateau Class I area (Sipsey Wilderness) had streams with the highest buffering capacity. (Note that the authors based their report on surveys conducted by others and did not account for potential differences in methods of data collection.)

A number of Federal areas contain estuarine and coastal areas that may experience eutrophication as a result of excess nitrogen deposition. For example, symptoms of eutrophication, including nutrient enrichment and algal blooms, have been observed in Everglades National Park and Chassahowitzka Wilderness (Florida).

3. LEGAL RESPONSIBILITIES

The specific legal responsibilities that Congress has given FLMs to protect natural, cultural, and scenic resources on the public lands from air pollution are identified in Appendix B. Statutes described in Appendix B. include agency organic acts, the Wilderness Act, and the Clean Air Act (CAA).

The fundamental Congressional direction for managing public lands arises out of respective organic acts. Each of these laws is essentially a charter from Congress to the Executive Branch providing a purpose for parks, wildernesses, and refuges, respectively, and establishing broad management objectives for these areas. The Wilderness Act sets aside a subset of these public lands where natural processes are allowed to dominate. The agency stewards develop specific management objectives building on the organic acts using public involvement, regulations, best available science, and additional direction provided by Congress.

Among this additional Congressional direction is the Clean Air Act (CAA). It further characterizes some of the public lands as Class I areas and directs the land managers to take an affirmative responsibility to protect these areas from air pollution. The CAA directs that the FLMs identify and protect air quality related values, including visibility. This direction is consistent with the underlying charters provided by the organic acts and the Wilderness Act. The similarities of management objectives, and of the policies and procedures necessary for protecting Class I areas, are at the core of the FLAG process.

In implementing laws, it is essential to understand the "intent of Congress." In the case of the CAA, the FLM gleans additional insight from a passage in Senate Report No. 95-127, 95th Congress, 1st Session, 1977 which states,

> "The Federal Land Manager holds a powerful tool. He is required to protect Federal lands from deterioration of an established value, even when Class I [increments] are not exceeded. … While the general scope of the Federal Government's activities in preventing significant deterioration has been carefully limited, the FLM should assume an aggressive role in protecting the air quality values of land areas under their jurisdiction. In cases of doubt the land manager should err on the side of protecting the air quality-related values for future generations."

Although the FLMs have an "affirmative responsibility" to protect AQRVs, they have no permitting authority under the CAA, and they have no authority under the CAA to establish air quality-related rules or standards. The FLM role consists of considering whether emissions from a new source may have an adverse impact on AQRVs and providing comments to permitting authorities (States or EPA). It is important to emphasize that the FLAG report is only a guidance document that explains factors and information the FLMs expect to use when carrying out their consultative role. It is separate from Federal regulatory programs.

The FLAG report describes the steps and process that the FLMs intend to go through in order to perform their statutory duties. Consequently, the scope of the FLAG report is to provide a more consistent approach for the three FLM agencies to evaluate air pollution effects on their resources, and to provide guidance to permitting authorities and permit applicants regarding necessary AQRV analyses. Although FLAG strives to be consistent with regulatory programs and initiatives such as the Regional Haze Rule and New Source Review Reform, no direct ties exist between FLAG and these regulatory requirements.

4. COMMONALITIES AMONG FEDERAL LAND MANAGERS

If a new source is proposed near two or more areas managed by different FLMs, the FLMs generally try to coordinate in their interactions with the permitting authority and with the applicant. For example, two or more FLMs involved in pre-application meetings typically try to minimize the workload for the applicant by reaching agreement on the types of analyses the application should contain. Beyond coordinating during permit review, FLMs currently base requests and decisions on similar principles regarding resource protection and FLM responsibilities. Listed below are the common principles in five areas of air resource management. In addition, Appendix C provides the FLM's "GENERAL POLICY FOR MANAGING AIR QUALITY RELATED VALUES IN CLASS I AREAS."

a. Identifying AQRVs

FLMs agree on the following definition of an AQRV:

> A resource, as identified by the FLM for one or more Federal areas, that may be adversely affected by a change in air quality. The resource may include visibility or a specific scenic, cultural, physical, biological, ecological, or recreational resource identified by the FLM for a particular area.

This definition is compatible with the general definition of AQRV that appears in the *Federal Register* (FR 15016, April 10, 1978). That definition includes visibility, flora, fauna, odor, water, soils, geologic features, and cultural resources. FLMs have the responsibility to identify specific AQRVs of areas they manage. To this end, FLMs further refine AQRVs beyond the above definition to be more site-specific (*i.e.*, area specific) by using on-site information. FLMs have developed inventories of specific AQRVs for many Class I areas and recognize that, ideally, inventories should be developed for all Class I areas. FLMs can be contacted for copies of site-specific AQRV lists. Finally, FLMs agree on the need for continued inventory, research, and monitoring to improve their ability to determine which AQRVs are most sensitive to air pollution and the sensitivity of these AQRVs.

b. Determining the Levels of Pollution that Trigger Concern for the Well-Being of AQRVs

FLMs believe that it should be possible to agree among themselves on the levels of pollution that trigger concerns for AQRVs. FLMs recognize the need to assess cumulative impacts and the difficulties associated with this process. Difficulties arise when a large number of minor source impacts eventually lead to an unacceptable cumulative impact or when a new source applies for a PSD permit in an area that has a high background concentration of pollution from existing sources. This means that a proposed new source should be evaluated within the context of the total impacts that are occurring or that potentially could occur from permitted/existing sources on the AQRVs of the area.

c. Visibility

FLMs use EPA-approved models to evaluate visibility impacts. The models use thresholds of visibility degradation measured in light extinction to evaluate source impacts to haze (far-field/multi-source impacts), and EPA established criteria for coherent plume impacts (near-field impacts). Currently all FLMs use Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring data to determine current conditions for visibility in FLM areas.

d. Biological and Physical Effects

All FLMs rely on research, monitoring, models, and effects experts to identify and understand physical, biological, and chemical changes resulting from air pollution and relating them to changes in AQRVs. Further, they focus on sensitive AQRVs (defined as either species or processes) to assess this biological/physical/chemical change.

e. Determining the Level of Pollution Likely to Cause an "Adverse Impact" on AQRVs

FLMs rely on the best scientific information available in the published literature and best available data to make informed decisions regarding levels of pollution likely to cause adverse impacts. FLMs re-evaluate, update, and assess this information as appropriate. They consider specific Agency and Class I area legislative mandates in their decisions and, in cases of doubt, "err on the side of protecting the AQRVs for future generations." (Senate Report No. 95-127, 95th Congress, 1st Session, 1977)

For air quality dispersion modeling analyses, FLMs follow 40 CFR §52.21(l) (Appendix W of Part 51, EPA's *Guideline on Air Quality Models*, revised 1996) and the recommendations of the Interagency Workgroup on Air Quality Modeling (IWAQM). FLMs recommend protocols for modeling analyses to permit applicants on a case-by-case basis considering types and amount of emissions, location of source, and meteorology. When reviewing modeling and impact analysis results, all FLMs consider frequency, magnitude, duration, and location of impacts.

f. FLM databases

Air Synthesis (formerly Air Quality Information Management System – AQUIMS)
Air Synthesis is an information management and decision-support computer system under development by NPS and FWS. Air Synthesis is designed to assist FLMs in determining potential effects of pollutants on AQRVs. It contains information on air quality and its effects in Class I parks and wildernesses as well as natural resource data and annotated bibliographies of current literature on ozone and deposition. The system will also contain an interactive expert system module that will allow FLMs to assess the current status of freshwaters and determine if these resources are affected by deposition of sulfur or nitrogen.

Natural Resource Information System – Air Module (NRIS-AIR)
The Air Module is part of the USDA/FS' Natural Resource Information System that integrates various physical, biological, and socioeconomic data within an integrated system of database, map-based spatial information, and analytical tools. Version 1.0 of NRIS-AIR, released in November 1998, tracks AQRVs, sensitive receptors, and indicators for each of the USDA/FS Class I areas. The water submodule provides data storage, reports, and tools for evaluating locally entered water quality and wet deposition data. Future NRIS-AIR versions (currently under development) will provide the information structure for visibility, flora, fauna, soil, geologic resources, cultural resources, and air quality data, as well as providing a PSD permit tracking system.

C. FEDERAL LAND MANAGERS' APPROACH TO AQRV PROTECTION

FLM responsibilities for resource protection on Federal lands are clear and there should be no misunderstanding regarding the tools the FLM uses to fulfill these responsibilities. Opportunities to influence decisions regarding pollution sources external to the park or wilderness are limited. However, FLMs strive to minimize emissions from internal sources and their effects. Approaches for minimizing air pollution from external and internal sources are discussed in detail below.

1. AQRV PROTECTION AND IDENTIFICATION

Congress assigned the FLMs an affirmative responsibility to protect AQRVs in Federal Class I areas. The FLMs interpret this assignment as a responsibility to:

1. Identify AQRVs in each of the Class I areas.
2. Establish inventorying and monitoring protocols for AQRVs.
3. Prioritize AQRV inventorying and monitoring (because of constrained budgets).
4. Specify a process for evaluating air pollution effects on AQRVs, including the use of sensitive indicators.
5. Specify adverse effects for each AQRV.

To the extent possible, AQRVs have been identified for each Class I area. Additional AQRVs may be identified in the future as more is learned through science about the sensitivity of resources to air pollution. Public involvement in this process is necessary and will be accomplished through participation in the land management planning process or reply to an announcement in the *Federal Register*.

While the sensitivity of an AQRV to air pollution may be known, the long term monitoring of its health or status may not have been accomplished. The expense of monitoring all AQRVs simultaneously is prohibitive. Consequently, FLMs seek opportunities through the permitting process and through partnerships to gather more information about condition of AQRVs.

Because AQRVs themselves are often difficult to measure, surrogates are used as indicators, or sensitive indicators, of the health or status of the AQRV. Designing a working process for Class I area management and AQRV protection is outlined ahead in this document.

Finally, an adverse impact is determined for each AQRV. An adverse impact from air pollution results in a diminishment of the Class I area’s national significance, that is, the reason the Class I area was created. Adverse impacts can also be an impairment of the structure or functioning of the ecosystem as well as an impairment of the quality of the visitor experience. The FLMs make an adverse impact determination on a case-by-case basis, based on technical and other information.

2. NEW SOURCE REVIEW

Section 165 of the CAA spells out the roles and responsibilities for FLMs in New Source Review, including the Prevention of Significant Deterioration (PSD) permitting program. Other laws, such as the respective agency organic acts and the Wilderness Act, provide the fundamental underpinning of land management direction to land managers. The following discussion merges this complex labyrinth of legal responsibilities as it relates to air resource management. A pending regulation revision from EPA which contains many of the items in this section addressing NSR may add more specificity to the Class I area protection process from the perspective of the CAA.

a. Roles and Responsibilities of FLMs

The FLM. The federal official directly responsible for the national parks, national wildlife refuges, and national forests (*e.g.*, park superintendents, refuge managers, and forest supervisors, respectively) derive their responsibility from the respective agency organic acts. Furthermore, these officials, and

Additionally, such dialogue facilitates coordination between permitting authorities and the FLMs. The significance of the impact to AQRVs is more important than the distance of the source. Not all PSD permit applications that the FLM is notified of will be analyzed in-depth by the FLM. FLM notification of a PSD permit application for a project located greater than 100 km does not mean that that application will be reviewed by the FLM in detail. Notification of PSD permit applications in excess of 100 km by the permitting authority allows the FLM to gauge the level of potential cumulative effects. As indicated above, the FLM decides which PSD permit applications to review on a case-by-case basis depending on the potential impacts to AQRVs.

Pre-Application Meetings. To expedite the PSD permit review process, the FLM encourages pre-application meetings with permitting authorities and permit applicants to discuss air quality concerns for a specific Class I area in question. Given preliminary information, such as the source's location and the types and quantity of projected air emissions, the FLM can discuss specific AQRVs for an area and advise the applicant of the analyses needed to assess potential impacts on these resources.

Completeness Determination. To further minimize delays, the FLMs encourage the permitting authority to use comments provided by the FLM concerning the completeness of the application, and to not deem the application complete until the applicant performs all necessary air quality impact analyses, including all relevant AQRV impact information. The permitting authority should then notify the FLM when they deem the application to be complete.

Visibility Protection Procedures. Additional procedural requirements apply when a proposed source has the potential to impair visibility in a Class I area (40 CFR §52.27(d)(1998)). Specifically, the permitting authority must, upon receiving a permit application for a source that may affect visibility in any Class I area, notify the FLM in writing. Such notification should include a copy of all information relevant to the permit application, including the proposed source's anticipated impacts on visibility in a Class I area. The permitting authority should notify the FLM within 30 days of receipt and at least 60 days prior to the close of the comment period.

If the FLM notifies the permitting authority that the proposed source may adversely impact visibility in a Class I area, or may adversely impact visibility in a previously identified integral (scenic) vista, then the permitting authority is to work with the FLM to address their concerns. If the permitting authority agrees with the FLM's finding that visibility in a Class I area may be adversely affected, the permit may not be issued. Even though the permitting authority may agree with the FLM's adverse impact finding regarding integral vistas, the permitting authority may still issue a permit if the emissions from the source are consistent with reasonable progress toward the national goal of preventing or remedying visibility impairment. In making this decision, the permitting authority may take into account the costs of compliance, the time needed for compliance, the energy and non-air quality environmental impacts of compliance, and the useful life of the source.

The FLM will make a preliminary determination regarding possible adverse visibility impacts within a prescribed time of receipt of all relevant information.

b. Elements of Permit Review

The FLM review of a PSD application for a proposed project that may impact a Class I area generally consists of three main analyses:

1. Air quality impact analysis to ensure that predicted pollutant levels in Class I areas do not exceed National Ambient Air Quality Standards (NAAQS) and PSD increments, and to provide sufficient information for the FLM to conduct an AQRV impact analysis. Ensuring that permit applicants meet these requirements is the direct responsibility of the permitting authority (see discussion below);

2. AQRV impact analysis to ensure that the Class I area resources (*i.e.*, visibility, flora, fauna, etc.) are not adversely affected by the proposed emissions. The AQRV impact analysis includes interpreting the significance of the results from the applicant's air quality impact analysis and is the responsibility of the FLM (see discussion below); and

3. Best Available Control Technology (BACT) analysis to help ensure that the source installs the best control technology to minimize emission increases from the proposed project (See Appendix D for a summary of this analysis). The final BACT determination is a direct responsibility of the permitting authority.

Air Quality Impact Analysis. The permit applicant must perform an air quality impact analysis for each pollutant subject to PSD review. This analysis should show the contribution of the proposed emissions to increment consumption and to the existing ambient pollution levels in a Class I park or wilderness area. The applicant should perform a cumulative increment analysis for each pollutant and averaging time for which the proposed source will have a significant impact. Because proposed sources are not yet operating, the air quality analysis must rely on mathematical dispersion models to estimate the air quality impact of the proposed emissions. The FLMs provide the applicants with guidance on where to place model receptors within the Class I area. The applicant is responsible to provide sufficient information for the FLM to make a decision about the acceptability of potential AQRV impacts as a consequence of the new source.

The applicant should perform the air quality impact analysis using approved models and procedures as specified in 40 CFR §52.21(l) and 40 CFR §51.166(l) (Appendix W of Part 51, EPA's *Guideline on Air Quality Models*, revised 1996 and in revision again as of the date of this writing, December 2000). The applicant should explicitly state all assumptions for the analysis, and furnish sufficient information on modeling input so that the FLM can validate and duplicate the model results. FLMs encourage the permit applicant to submit a modeling protocol for review before performing the Class I modeling analyses. This protocol should include the proposed air quality analysis methodology and model input (*i.e.*, emissions, stack data, meteorological data, etc.), and the proposed location of the receptors in the FLM area.

AQRV Impact Analysis. According to the CAA's legislative history and current EPA regulations and guidance, the air quality impact analysis that provides sufficient information to enable the FLM to conduct the AQRV impact analysis is one part of a permit application just as are the BACT analysis and the air quality impact analysis relative to the increments and NAAQS. The applicant bears the entire cost of preparing the permit application including the complete air quality impact analysis.

The FLM then uses the results from the applicant's air quality impact analysis and other information to conduct the AQRV impact analysis and make an informed decision about whether or not AQRVs will be adversely affected. If the FLM concludes that AQRVs are or will be adversely affected, the FLM must so demonstrate to the permitting authority. The following sections of this document give guidance to applicants on how to conduct an air quality impact analysis and how the FLM uses this information to make an AQRV impact decision.

Cumulative Impact Analysis. The applicant's air quality impact analysis should include both the permit applicant's contribution to the AQRV impacts, as well as the cumulative source impacts on AQRVs. A cumulative air quality analysis in which the proposed source and any recently permitted (but not yet operating) sources in the area are modeled is an important part of any AQRV impact analysis. This cumulative modeled impact is then added to measured ambient levels (to the extent that such monitoring data are available) so that the FLM can assess the total effect of the anticipated ambient concentrations on AQRVs. If no representative monitoring data are available, the applicant should estimate the total pollutant concentrations by modeling emissions from all contributing sources in the area.

Information Provided by the FLM to the Applicant. To assist the permit applicant in performing air quality impact analyses, the FLMs will provide all available information about AQRVs for a particular Class I area that may be adversely affected by emissions from the proposed source. FLMs will recommend available methods the applicant should use to analyze the potential effects to the receptor(s) located in the Class I area. In addition to identifying AQRVs, FLMs will, to the extent possible:

(1) identify inventories, surveys, monitoring data, scientific studies, or other published reports that are the basis for identification of AQRVs;

(2) identify specific receptors known to be most sensitive to air pollution and the pollutant or pollutants that individually or in combination can cause or contribute to an adverse effect on each receptor;

(3) Identify the critical pollutant concentrations above which adverse effects are known or suspected to occur;

(4) Recommend methods the applicant should use for predicting ambient pollutant concentrations and other related impacts (*e.g.*, deposition, visibility) which may cause or contribute to an adverse effect on each receptor; and

(5) Suggest screening level values or criteria that would be used to assess whether a proposed emissions increase would have a *de minimis* impact on AQRVs.

It is important to highlight the distinction between the air quality impact analyses that the applicant performs and the AQRV impact analyses that FLMs perform. Whereas the permit applicant calculates changes in pollutant concentrations, deposition rates, or visibility extinction, the FLM assesses the extent to which these impacts affect sensitive visual, aquatic, or terrestrial resources. Given the FLM's statutory responsibilities and expertise, the FLM must have responsibility to consider whether the amount of pollution dispersed into the air or deposited on the ground (or in water) would have an adverse impact on any AQRV, and if so, to demonstrate that claim to the permitting authority. In making an adverse impact finding, FLMs consider such factors as magnitude, frequency, duration, location, and timing of impacts, as well as current and projected conditions of AQRVs based on cumulative impacts.

c. FLM Permit Review Process

The FLM's current permit review process for any application that may impact a FLM area is described below.

1. **Pre-application**. If possible, participate in any pre-application meeting to learn specifics of the proposed project (size, emissions, location, etc.) and to provide information regarding recommended Class I analyses.

2. **Completeness Determination.** Upon receipt, the FLM will review the application and provide comments to the permitting authority regarding the completeness of the application and the need for additional information regarding the BACT, Air Quality Impacts, and AQRV Impacts analyses. The FLM will coordinate with the permitting authority and the permit applicant to ensure that all the necessary information to enable the FLM to make an impact determination is included.

3. **Public Comment Period**. After review of all relevant information, the FLM will provide pertinent comments to the permitting authority, before or during the official public comment period, and/or at scheduled public hearings.

4. N**o Class I Increment Violated and No Adverse Impacts.** If no Class I increment is violated and no adverse impacts to AQRVs are expected, the FLM will inform the permitting authority of this determination and no further FLM action is necessary. The FLM may still provide BACT comments.

5. **No Class I Increment Violated but AQRV Impact Uncertainty.** If no Class I increment is violated but uncertainty exists regarding potential adverse impacts to AQRVs, the FLM may request that the permitting authority include a permit condition that requires the permittee to conduct relevant post-construction AQRV or air quality monitoring. The FLM may also request certain control technologies or methods to reduce impacts.

6. **Class I Increment Violated, but No Adverse AQRV Impacts.** If the Class I increment is violated, but no adverse AQRV impacts are anticipated, the applicant requests the FLM to "certify" no adverse impact under Section 165(d)(2)C)(iii) of the Clean Air Act [42 USC 7475(d)(2)(C)(iii)(1998)]. If the FLM concurs, (s)he makes a preliminary determination that no adverse impacts will occur.

   a. The FLM will inform the applicant, the State/local permitting authority, and EPA of the preliminary no adverse impact determination.

   b. The FLM will notify the public of its preliminary no adverse impact determination either through the permitting authority's notice procedures, or through separate notice in the *Federal Register*. Such notice should include a statement as to the availability of supporting documentation for inspection and copying, and an announcement of at least a 30-day public comment period on issues directly relevant to the determination in question.

   c. The FLM will review and prepare response to public comments.

d. The FLM will make a final determination regarding no adverse impacts, with a clear and concise statement of reasons supporting that determination.

e. The FLM will inform the permit applicant, the permitting authority, and EPA of its final determination and if the final determination is "no adverse impact," the FLM shall so "certify" in a letter to the affected parties.

f. Simultaneous with step e, the FLM will publish a final determination in the "Notice" section of the *Federal Register*, including a clear and concise statement of reasons supporting that determination, statement as to availability of supporting documentation for inspection and copying, and statement as to immediate effective date (date signed) of final determination.

g. The FLM will contact the permitting authority and request a revision to the State Implementation Plan (SIP) to eliminate the Class I increment violations.

7. **Adverse Impact Determination.** Regardless of increment status, the FLM may make a preliminary determination that the proposed project will cause, or contribute to, an adverse impact on AQRVs. Before officially declaring an adverse impact, the FLM will inform the proposed new source and the permitting authority that an adverse impact determination is imminent and suggest that the permit be modified. If the permit is modified to satisfy the concerns of the FLM, then an adverse determination is avoided.

a. The FLM will inform the applicant, the permitting authority, and EPA of a preliminary adverse impact determination.

b. The FLM will notify the public of the preliminary adverse impact determination either through the permitting authority's notice procedures, or through separate notice in the *Federal Register*. Such notice should include a statement as to the availability of supporting documentation for inspection and copying, and an announcement of at least a 30-day public comment period on issues directly relevant to the determination in question.

c. The FLM will review and prepare response to public comments.

d. The FLM will make a final determination regarding adverse impacts, with a clear and concise statement of reasons supporting that determination.

e. The FLM will inform the permit applicant, the permitting authority, and EPA of its final determination.

f. Simultaneous with step e, the FLM will publish a final determination in the "Notice" section of the *Federal Register*, including a clear and concise statement of reasons supporting that determination, statement as to availability of supporting documentation for inspection and copying, and statement as to immediate effective date (date signed) of final determination.

g. If the FLM makes a final determination that a source will have an adverse impact, the FLM will oppose the permit. However, the permit applicant may propose to mitigate any adverse impacts (via reducing emissions, obtaining emission offsets, etc.). If the applicant adequately mitigates the adverse impacts to the satisfaction of the FLM, the FLM will withdraw his objection to the permit. If the adverse impacts are not adequately mitigated and the permitting authority nevertheless issues the permit, the FLM may appeal the permit.

Note: If the permitting authority's SIP makes execution of the above listed steps impossible (*e.g.*, inadequate time allotments for the FLM's determination or lack of timely FLM notice) the procedures visitor use of the Federal class I area, and (2) the frequency and timing of natural conditions that reduce visibility. (Id. §51.301(a))

FLMs typically address adverse impacts on a case-by-case basis in response to PSD permit applications. When an adverse impact is predicted, FLMs recommend that permits either be modified to protect AQRVs or be denied. FLMs can also address adverse conditions outside of the PSD process. To do so, they: certify visibility impairment; participate in regional assessments; informally collaborate with States and EPA; review lease permits, SIP revisions, National Environmental Policy Act (NEPA) analyses, Park/Refuge/Forest management plans, CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act) reviews, and other documents.

In some States, FLMs use screening procedures or thresholds that indicate when the condition of an AQRV is acceptable or unacceptable. The pollutant concentration or loading rate that will adversely impact an AQRV can vary among Class I areas, and depends on current conditions. After a threshold is reached, an increase in pollutant concentrations is likely to be unacceptable. A concern threshold can be an adverse impact threshold or other quantifiable level in resource condition or pollutant exposure identified by the FLM.

e. Air Pollution Permit Conditions that Benefit Class I Areas

The FLM does not determine what permit conditions will be required or administer permit conditions; that is the responsibility of the permitting authority. However, the FLMs may request permit conditions or agree to withdraw objections to permit issuance if requested conditions are included. The FLMs view the inclusion of certain PSD permit conditions by the permitting authority as a means to help protect or enhance the condition of AQRVs when:

1. Air pollution source(s) may cause impacts that exceed protection thresholds for AQRVs;
2. Terrestrial resources, aquatic resources, and/or visibility are currently adversely impacted by air pollution and proposed emissions will exacerbate these adverse conditions;
3. FLM policies require improvement or restoration of AQRVs in parks and wildernesses; and
4. There is uncertainty on the extent and magnitude of air pollution effects on AQRVs.

Permit conditions may require emission offsets, AQRV and/or air quality monitoring, inventories, re-openers**,** LAER (or other improved control technologies), or other measures to protect, enhance, or restore resources and values of parks and wildernesses. Permit conditions may:

1. Result in net air quality benefits at a protected area or within a region;
2. Contribute to a reduction of air pollution within a region;
3. Promote ecosystem inventories and/or monitoring to evaluate physical and biological resource damage caused by air pollution emissions; and
4. Promote ecosystem restoration or improve the condition of resources damaged by air pollution emissions.

The basis of an air permit condition may be identified in the public notice for the draft permit. To be effective, permit conditions must be federally enforceable and guaranteed. Air permit provisions may be temporary or permanent depending on the nature of the permit requirements. Procedures to implement an air permit condition must be acceptable to the FLM (*e.g.*, an agreement between parties [memorandum of understanding, interagency agreement] is an option to accomplish inventory, monitoring, or other requirements).

f. Reducing Pollution in Nonattainment Areas (Nonattainment Permit Process)

The PSD program does not apply with respect to a particular pollutant when the source locates in an area designated non-attainment for that pollutant. Instead, pollution sources are regulated by Non-attainment Area New Source Review (NNSR). NNSR includes air quality planning and regulation of stationary sources. Air quality planning addresses issues such as lowest achievable emission rate (LAER), offsets, reasonably available control technology (RACT), and mobile and stationary source control strategies. New major stationary sources and major modifications of sources in designated non-attainment areas must satisfy NNSR before construction begins. For visibility protection, SIPs must include either EPA-approve provisions to comply with 40 CFR §51.307 for the non-attainment pollutant, otherwise, the federally promulgated visibility provisions at 40 CFR §52.28 would apply to all sources located in non-attainment areas. Therefore, FLMs can provide suggestions to the permitting authority regarding these conditions during the permitting and planning processes.

SIPs provide a mechanism to address AQRV impacts for when the source or the Class I area is located in a non-attainment area. Land managers should recommend that States adopt policies, rules, or regulations in their SIPs requiring a demonstration that offsets will result in a net air quality benefit within any Class I area likely to be impacted by emissions from the source to be permitted. FLMs may also request emissions reductions greater than 1:1, perhaps offset rates of 1.5 or 2.0 to 1, or higher, depending on the impacts to be offset. Such recommendations can be developed jointly in a meeting with the regulatory authority or in a letter from the FLM.

Mitigation measures recommended by FLMs may include stringent control technologies to minimize the increase in emissions and the impact on AQRVs. Monitoring can determine whether predicted resource conditions are observed. Offsets ensure that net emissions reductions from all sources will occur within a geographic area and their resulting air quality impacts at the Class I area will be mitigated.

3. OTHER AIR QUALITY REVIEW CONSIDERATIONS

At all Class I areas where visibility has been monitored, visibility conditions have been found to be impaired (by human-caused pollution). The impairment comes primarily from older sources, not new sources. From a regional perspective, new or modified sources (using new/cleaner technologies) contribute far less to impaired AQRV conditions than old sources. New programs, such as EPA's NAAQS for fine particulate matter and 8-hour ozone levels have been legally challenged (as of December 2000) so their effectiveness in reducing overall regional pollutant levels from older sources is uncertain at this time. EPA has implemented a call for reducing NO_x emissions from older sources in the eastern U.S. to meet existing ozone standards, however, this action is being appealed to the U.S. Supreme Court. In addition to national ambient standards, most States are just now beginning the planning process to implement EPA's Regional Haze Regulations. If all of these requirements are implemented, then progress toward remedying impaired AQRVs is likely. However, given the sensitivity of some AQRVs to low levels of pollution, programs focused on reaching national goals, such as the NAAQS or visibility, may not fully remedy impacts on AQRVs in all locations. It is for this reason that the FLM should pursue all other reasonable strategies to protect AQRVs. The following sections discuss FLM issues that go beyond NSR.

a. Remedying Existing Adverse Impacts

The existence of adverse impacts is unacceptable to FLMs and contrary to the mandates of their specific agencies. Consequently, FLMs may request or participate in regional assessments to protect AQRVs, as appropriate. Regional assessments often use a multi-faceted approach to remedy impairment. For example, categories addressed by the Grand Canyon Visibility Transport Commission (GCVTC) include air pollution prevention; clean air corridors; stationary sources; sources in and near Class I areas; mobile sources; road dust; fire; and future regional coordination.

Clean Air Act requirements for remedying existing visibility impairment provide a mechanism for addressing impacts from specific sources or groups of sources. Negotiations at the Centralia Power Plant in the state of Washington provide an example of how to build partnerships and work collaboratively to obtain retrofit controls or more stringent control technologies for sources that affect a FLM area. Through a collaborative decisionmaking process, owners of the Centralia plant agreed to reduce sulfur dioxide emissions at the plant by 90%. In another case, the USDA/FS asked the state of Colorado to remedy existing impairment at Mt. Zirkel Wilderness. Following USDA/FS testimony about the Mt. Zirkel Wilderness, terms of a court-ordered consent decree that specified controls for the Hayden Power Plant were included in Colorado’s long-term visibility strategy.

FLMs may also coordinate with others to ensure that emission reductions in nonattainment areas will improve air quality in FLM areas. Recommendations on urban planning were developed with FLM involvement to address nonattainment areas in California. Data documenting ozone effects on vegetation were provided to the planning authority.

b. Requesting SIP Revisions to Address AQRV Adverse Impacts

A SIP is the key vehicle a state uses to develop the pollution control programs that will be used to achieve and maintain the NAAQS as well as prevent significant deterioration of air quality. It is important for FLMs to be involved in SIP development, as participation provides an opportunity to influence planning of pollution control programs that can benefit air quality in FLM areas. Once a SIP is fully approved by EPA, it is legally enforceable under both State and Federal law. FLMs can use the SIP process to address existing impacts that are unacceptable by requesting a SIP revision. This approach is particularly useful for addressing impacts on AQRVs other than visibility, since the Clean Air Act does not provide specific requirements for other AQRVs. In an October 16, 1996, letter from the Deputy Assistant Administrator of the EPA to the Assistant Secretary of the Department of the Interior (DOI), the EPA acknowledged that the CAA provides authority to address adverse impacts on AQRVs in Class I areas from both new and existing sources. EPA committed to initiate rulemaking that will set forth the affirmative obligation for States to protect AQRVs as part of their CAA responsibility to prevent significant deterioration of air quality. EPA states this approach would require the protection of AQRVs as part of SIPs.

In an October 17, 1996, response, DOI offered to assist EPA in developing this adverse impact SIP rulemaking. In addition, DOI urged EPA "to require State Implementation Plans to prevent significant deterioration of air quality by adopting mitigation measures to address adverse impacts on AQRVs in Class I areas." These SIP revisions could be used to address multiple sources and regional pollution that adversely affect AQRVs in all Class I areas. DOI sent a follow-up letter to EPA in July 2000 reiterating the need for an AQRV "restoration and protection" rulemaking. EPA solicited public input regarding an AQRV rule, as well as a request from Northeastern states for more stringent secondary NAAQS. EPA will consider comments received and then decide on a course of action.

South Coast and San Diego, California, SIP revisions included FLM recommendations to reduce the impact of minor sources on AQRVs. South Coast recommendations addressed visibility while the San Diego recommendations addressed all AQRVs. EPA's NO_X SIP Call in the east is another example of obtaining emission reductions through the SIP revision process. The NO_X SIP Call is directed at 20 eastern States and the District of Columbia to address NO_X emissions from existing large sources. Once this action is implemented, significant reductions in ozone formation and nitrogen deposition are anticipated.

c. Periodic Increment Consumption Review

As mentioned above, EPA has indicated its intention to the FLMs to establish a SIP revision requirement to address existing adverse impacts on AQRVs. The FLMs strongly support EPA exercising its authority in this way. In the interim, however, there are existing SIP revision requirements that are not being fully utilized. EPA's current regulations require States to conduct a periodic review of the adequacy of their PSD plan and program. [40 CFR §51.166(a)(4)] This would include an assessment of increment consumption in Class I and Class II areas. Few States have ever conducted a comprehensive, cumulative increment consumption analysis for one or more Class I areas. In addition, many PSD sources have not exceeded the significant impact levels for increment consumption; thus, few PSD permit applicants have had to perform a cumulative increment consumption analysis for Class I areas. Such a periodic increment consumption review would be beneficial given that the burden of proof for AQRV adverse impact determinations shifts from the FLM to the applicant when the increment has been consumed.

In its 1990 report *Air Pollution: Protecting Parks and Wilderness From Nearby Pollution Sources* the U.S. General Accounting Office (GAO) found that only 1 percent of the sources within 100 kilometers of five Class I areas it investigated were required to have permits under the PSD program, with 99 percent of the sources being minor or grandfathered sources. It also found that "non-PSD sources contribute from 53 to 90 percent of five of the six criteria pollutants emitted within a 100-kilometer radius of each of the 5 Class I areas." As part of its investigation, GAO noted that "a significant portion of total emissions of volatile organic compounds generally comes from small sources...and suggested that as part of the overall control strategy, States may want to consider lowering thresholds for regulating new sources to 25 tons of volatile organic compounds a year." According to the investigation, 55 percent of anthropogenic VOC emissions come from new sources or modifications totaling 5 tons per year or less. In a review of PSD permit applications near Mesa Verde National Park (a Class I area in Colorado), a cumulative modeling analysis of increment-consuming sources found that approximately 80 percent of the NO_2 Class I increment at the park had been consumed, but much of it by minor sources.

The FLMs have encouraged EPA to provide clearer direction on how often these periodic reviews must occur as the lack of a prescribed time-frame for conducting such analyses has clearly led to noncompliance with this requirement over the past twenty years by States. The FLMs believe EPA should revise 40 CFR §51.166 to require that the periodic reviews be conducted no less frequently than every five years.

4. MANAGING EMISSIONS GENERATED IN AND NEAR FLM AREAS

Specific strategies need to be developed and implemented for reducing and preventing pollution from the many diverse sources and activities in communities surrounding FLM areas, including "gateway" communities. Accountability mechanisms are needed to ensure that appropriate actions are taken, reported and incorporated into SIPs, visibility protection plans, and Federal land management plans. Various forums (*e.g.*, the Western Regional Air Partnership, and the Southern Appalachian Mountains Initiative) are addressing some of the emissions sources of concern and developing appropriate regional strategies. In addition, EPA has formed other "regional planning organizations" for implementing its regional haze rule. FLMs should participate in these forums, consistent with Federal law (*e.g.*, Federal Advisory Committee Act), to the maximum extent possible and should coordinate their activities within those forums to ensure that comprehensive strategies are developed and implemented to address all the key emissions sources near FLM areas.

A systematic assessment of emission sources in and near FLM areas would be extremely helpful for formulating strategies aimed at mitigating or eliminating adverse impacts on area resources. Without this assessment it is not possible to accurately quantify the extent to which these emissions contribute to the overall problem. Nevertheless, FLMs can, and should, take steps to minimize emissions generated on FLM lands even without an accurate inventory of emissions sources.

a. Prescribed Fire

Prescribed fire is a land management tool used for multiple landscape objectives. Prescribed fire allows the FLM to mimic natural fire return intervals under controlled conditions where smoke management can minimize air quality impacts. The alternative is wildfires, which can be very difficult to control and may cause much more severe air quality impacts. A modeling assessment suggests that using prescribed fire to minimize wildfires can result in a net reduction in fine particle ($PM_{2.5}$) emissions in the long term. In the Pacific Northwest wildfire emissions were found to be greater than prescribed fire emissions in the same airshed (Ottmar, 1996).

Since the turn of the century, wildfire has been aggressively suppressed on most of the nation's public lands to protect public safety, property, and to prevent what was thought to be the destruction of our natural and cultural resources. Fire-exclusion practices have resulted in forests, shrub lands, and grasslands plagued with a variety of problems, including overcrowding, resulting from the encroachment of species normally suppressed by fire; vulnerability of trees to insects and disease; and inadequate reproduction of certain species. In addition, heavy accumulation of fuels (such as dead vegetation on the forest floor) can cause fires to be catastrophic, which threatens firefighter and public safety, impairs forest and ecosystem health, destroys property and natural and cultural resources, and degrades air quality. The intense or extended periods of smoke associated with wildfires can also cause serious health effects and significantly decrease visibility.

FLMs recognize prescribed fire as a valuable tool; they also recognize that emissions from prescribed fire can be a significant source of air pollution. Smoke particles are also in the size range (< 2.5 µm) that they play a significant role in visibility impairment. Particulate matter is the main pollutant of concern from smoke because it can cause serious health problems, especially for people with respiratory illness.

The FLMs are committed to minimizing the impacts from smoke by following sound smoke management practices, and if practical, using alternative methods to achieve land management objectives. Each prescribed burn site will have unique characteristics, but in general, smoke impacts can be greatly minimized by burning during weather conditions that provide optimal humidity levels and dispersion conditions for the type of materials being burned, in addition to limiting the amount of materials and acreage burned at one time.

Generally, fire inside wilderness is considered natural–there is a need whenever possible to allow these fires to burn out naturally when the fires do not threaten private property or air quality conditions do not threaten human health. Visibility impairments caused by naturally ignited fires in wilderness should similarly be classified as natural. Unlike stationary source emissions, which are continuous, fire emissions are spatially and temporally sporadic.

EPA has worked in partnership with land management agencies in the U.S. Departments of Agriculture, Defense, and the Interior; State Foresters; State air regulators; Tribes; and others to obtain recommendations and develop a national policy that addresses how best to improve the quality of wildland ecosystems (including forests and grasslands) and reduce threats of catastrophic wildfires through the increased use of managed fire, while achieving national clean air goals (U.S. EPA, 1998). EPA's wildland fire policy describes criteria for wildland managers (federal, state, tribal, and private), and state and tribal air pollution agencies, to use in planning for and implementing prescribed fires, and recommends a variety of smoke management techniques that land managers can use to help reduce smoke impacts from prescribed fires. The policy is available at EPA's website: http://www.epa.gov/ttn/faca/fa08.html.

b. Strategies to Minimize Emissions from Sources In and Near FLM Areas

Aside from prescribed fire, other activities that generate air pollution in FLM areas include road building, operation of generators, oil and gas development, etc. Developing strategies for addressing natural resource impacts in or near an FLM area should not only take into consideration the type of activities generating the emissions and their amount, but also the existing condition of the resources of that area. More stringent measures should be required for sources in and near FLM areas that are already experiencing adverse effects from air pollution.

Examples of potential air pollution prevention practices that FLM agencies may encourage or develop and use are categorized under the following three strategies:

Pollution Prevention Strategies

- Review land management plans for affected FLM areas to assess whether they include strategies to limit and reduce air pollution emissions and incorporate protective measures into planning and decision documents.
- Place priority on pollution prevention.

- Encourage zero and near-zero emitting technologies.
- Promote energy conservation and the use of renewable energy sources.
- Promote use of clean fuels.

Mobile Source Strategies

- Promote the adoption of Low Emission Vehicle standards or the conversion of Federal fleets to alternative fuels.
- Improve control of evaporative emissions.
- Adopt and enforce more stringent emission standards for the tour bus industry and other high-emitting vehicles (*e.g.*, snowmobiles).
- Retire high-emitting vehicles from Federal fleets as quickly as possible and/or relocate high-emitting vehicles to less sensitive areas until they can be retired.
- Establish emission budgets from the transportation sector for selected FLM areas.
- Develop mass transit systems in some NPS units (*e.g.*, light rail in Grand Canyon NP and a bus system in Zion NP).

Minor Source Strategies

- Apply RACT, BACT, LAER, best and reasonably available control measures, etc., to existing sources, as appropriate.
- Go beyond conformity requirements to include the protection of AQRVs in FLM areas by ensuring all actions FLMs can practicably control in and near FLM areas will not cause, or contribute to, an adverse impact on any AQRV.

Improved involvement with interested parties in gateway communities (those adjacent to FLM areas) will likely be required to ensure growth in these communities occurs in a manner that mitigates the impact on natural resources. These communities may need to enhance their participation in the planning processes of FLMs. Similarly, FLMs must participate in planning activities for public lands located in the FLM area and communities adjacent to FLM areas to ensure air quality concerns are adequately addressed. Mechanisms must be identified and developed for community involvement in developing, implementing, and enforcing emission management strategies for sources near and in FLM areas.

Implementing strategies to achieve emission reductions in and near FLM areas will require efforts in at least three specific areas:

1. FLMs should ensure that sufficient emphasis is placed in agency planning documents requiring the minimization of air pollution emissions from new activities or practices.

2. FLM agencies should inventory air pollution emissions within FLM areas. After emissions have been quantified, FLMs, States, and adjacent communities will be able to assess the impact of these emissions through the use of appropriate models. Knowledge of Class I area emissions will also improve FLM ability to consult with States during the development and review of their SIPs (especially visibility SIPs).

3. FLMs should cooperate with States and local communities in assessing the need for, and the development of, appropriate emission reduction strategies in and near FLM areas that address non-

PSD sources. Without an acknowledgment from States and local communities that these sources may pose a threat to FLM areas and a systematic assessment of these potential impacts, current efforts to protect FLM area resources may be insufficient.

c. Conformity Requirements in Nonattainment Areas

Conformity criteria and procedures ensure that actions on lands administered by Federal agencies do not cause a violation of the NAAQS, increase the frequency of any standards violations, or delay attainment. Conformity to SIPs is only required for activities within nonattainment areas for non-transportation related sources if emissions are above *de minimis* levels and regionally significant. Any activity that represents 10 percent, or more, of the emission inventory for that pollutant in the non-attainment or maintenance area is regionally significant. Examples of actions that may require a conformity determination include road paving projects, ski area development, or mining. Activities such as prescribed fire, that are included in a conforming land management plan, are exempt from conformity requirements.

The FLM should define the process to be used in conformity determinations and perform the conformity analysis before a project is implemented. A conformity analysis typically includes emission calculations, public participation, mitigation measures/implementation schedules, and reporting methods. The Pacific Southwest Region of the USDA/FS has published a *Conformity Handbook for FLMs* to assist in conformity compliance. In an approved Plan of Operation, FLMs can require monitoring. For example, in the case of Carlota Mine, located on National Forest land in Arizona, the USDA/FS requested additional mitigation measures to protect AQRVs in the Superstition Wilderness.

Transportation projects in FLM areas classified as nonattainment are subject to a more complicated transportation conformity process. Consultation with State and local air quality and transportation agencies will be required to comply with applicable regulations.

D. SUBGROUP REPORTS: TECHNICAL ANALYSES AND RECOMMENDATIONS

1. SUBGROUP OBJECTIVES AND TASKS

Subgroups were formed to address the four key issues relevant to AQRV identification and evaluation issues: policy (and procedures), visibility, ozone, and deposition. Each of these subgroups reviewed the commonalities among the FLMs then addressed the tasks assigned to them by FLAG. One of their first tasks was to differentiate between Phase I tasks, those which could be resolved in the short term without significant additional resources, and Phase II issues, those that would require a longer period or greater effort.

thresholds, and decision thresholds. These are all interrelated. The levels of concern are visibility impact levels that would alert the FLM to a need for closer scrutiny. The analysis thresholds parallel these levels of concern in that if visibility impacts approach the levels of concern, the FLM would need to see further analyses to make an informed judgement about those impacts. The decision thresholds correspond to the visibility impacts, below which the FLM is not likely to object to an increase in visibility impairing pollutants. It is important to note that the decision thresholds can not be absolute; the FLM is required to make a determination on a "…case-by-case basis taking into account the geographic extent, intensity, duration, frequency and time of visibility impairments…" (40 CFR §51.301 (a)). However, the decision thresholds should be useful as an initial benchmark for analysts to judge whether visibility impacts would likely cause the FLM to object to a proposed action.

Natural Conditions

Comparing the impacts of new source growth against natural conditions implies that natural conditions are defined. At the time of this writing (December 2000) the EPA is working on defining natural conditions in support of their visibility regulations, but that work has not yet been completed. An estimate of natural conditions has been made (NAPAP, 1990). These estimates are only differentiated by the broad categories of the eastern and western United States. FLAG has adopted the appropriate aerosol concentrations from the NAPAP as estimates of natural conditions for each Class I area (Appendix 2.B). These estimates are a surrogate to be used until more definitive values for natural conditions are established.

Visibility Impairment

Before proceeding with the discussion, it is useful to identify the ways that visibility impairment can manifest itself. First, the pollutant loading of a section of the atmosphere can become visible, by the contrast or color difference between a layer or plume and a viewed background, such as a landscape feature or the sky. The second way that visibility is impaired is a general alteration in the appearance of landscape features or the sky, changing the color or the contrast between landscape features or causing features of a view to disappear. The first phenomenon is commonly referred to as plume impairment, whereas the second phenomenon is sometimes referred to as uniform haze impairment. As plumes are transported within a stable atmospheric layer, they may become a layered haze. As plumes and other more diffuse emission sources are transported and become well mixed in the atmosphere, they may develop into a uniform haze.

Visibility Parameters

The analysis methods for new source growth, described in this chapter, only deal with the visibility effects of discrete plumes and the aggregation of discrete plumes. The difference in these phenomena, as treated in this chapter, is whether the visibility effect is primarily seen as a section of the atmosphere which exhibits a change in contrast or color as compared with a viewed background, or whether the effect is due to an alteration of the appearance of the background features themselves. For the first situation, the contrast (C) and color difference index (ΔE) of the plume and the viewing background are calculated. For the second situation, the change in atmospheric light extinction (Δb_{ext}), relative to natural conditions, is calculated. An approximation for which situation applies is the distance from the point of emission. (Distance serves as an indicator of where steady state conditions may apply.) The visibility impairment from sources within 50 kilometers of a view is usually calculated using contrast and color difference, where visibility impairment from sources greater than 50 kilometers from a view, or the aggregation of a number of plumes, regardless of distance, is usually calculated using the change in light extinction. The distance approximation is useful for distinguishing these two phenomena; the terms "near field" and "distant/multi-source" are sometimes used in the remainder of this document to make this distinction. More information on visibility parameters can be found in Appendix 2.A.

Levels of Concern

The crucial level of concern for visibility impairment is whether it is humanly perceptible as compared against natural conditions (40 CFR §51.301(x)). As noted above, different visibility parameters are applied for different phenomena. A summary of the thresholds of perceptibility for the case of a plume viewed against a background indicates that contrast values (C) of ±0.01 to ±0.05 (note that the sign denotes whether the plume is brighter (+) or darker (-) than the background) are perceptible (NAPAP, 1990). A change in the color difference index (ΔE) of less than 1 to 4 has been identified as the range of perceptibility for this parameter. The Workbook for Plume Visual Impact Screening and Analysis (USEPA, 1992a) suggests that a level of 0.05 for the absolute value of contrast ($|C| = 0.05$) and $\Delta E = 2$ be used as thresholds in screening analyses; these levels were set in the mid-range of the perceptibility thresholds, in part, because of the conservative nature of the screening calculations. These levels also constitute the FLM's level of concern for screening analyses of plumes viewed against a background. Under circumstances of a more refined analysis, $|C| = 0.02$ and $\Delta E = 1$ are the levels of concern (USEPA, 1992b). These levels are usually applied for near field analyses where single sources are locating within 50 kilometers of a view.

For the case of visibility impairment which changes the appearance of a viewed background feature, thresholds of perceptibility, where a just noticeable change occurs in the scene, have been found to correspond to a change in extinction (Δb_{ext}) as low as 2% under ideal conditions, up to 20% (NAPAP, 1990; Pitchford and Malm, 1994). A Δb_{ext} of 5% will evoke a just noticeable change in most landscapes (NAPAP, 1990). The FLMs are concerned about situations where a change in extinction from new source growth is greater than 5% as compared against natural conditions. Changes in extinction greater than 10% are generally considered unacceptable by the FLMs and will likely raise objections to further pollutant loading without mitigation. These levels are usually applied for distant/multi-source analyses where sources are located more than 50 kilometers from a view or for analyzing the visibility impairment from an aggregation of plumes from multiple sources, regardless of distance.

Cumulative Analyses

A cumulative effects analysis of new source growth (defined as all PSD increment-consuming sources) on visibility impairment should be performed. The change in extinction (Δb_{ext}) will usually be the visibility parameter examined. The FLMs recognize that cumulative analyses of the effects of new source growth on visibility impairment have only rarely been carried out. Until cumulative analyses are performed for an area, the FLMs are suggesting some analysis thresholds

to either trigger a cumulative analysis or allow a source to be permitted if its impact is below certain prescribed levels.

If a cumulative analysis has already been performed for the area, or if other considerations (*i.e.*, NEPA, PSD increments, or other AQRV analyses) require that a cumulative analysis be performed for the proposed source, then the visibility impacts of the source are expected to be considered as part of the cumulative visibility impairment, as compared against natural conditions. When these conditions are met, the inclusion of the proposed source is expected regardless of the predicted visibility impairment of the source, unless its impacts are considered below *de minimis*.

Analysis Thresholds for New Cumulative Analyses

The analysis thresholds outlined here are interim levels to be used until such time as cumulative analyses are conducted for an area. Change in extinction (Δb_{ext}) is usually the visibility parameter analyzed for a cumulative analysis. If the visibility impact of a proposed project is below 0.4%[*] change in extinction, the impacts would be considered below *de minimis* and would not require further analysis. For situations where a cumulative visibility analysis has not been done or is not required because of other considerations, the following analysis thresholds will apply. If the visibility impact of a proposed source is less than a 5% change in extinction a cumulative analysis would not be expected. For visibility impairment predicted to be above 5%, but less than 10%, change in extinction from a proposed source, a cumulative analysis is expected. If the visibility impairment is predicted to be greater than 10% from a proposed source, the FLM is likely to object to the project regardless of other source growth, unless there is mitigation.

Decision Thresholds

Each determination of whether the impacts from a new source or major modification will be considered adverse must, by regulation, be made on a case-by-case basis (40 CFR §51.301(a)). Therefore, the decision thresholds specified here are strictly a guideline. More refined visibility analyses may indicate that the visibility parameters used (*i.e.*, C, ΔE, Δb_{ext}) do not adequately characterize the visibility for a particular situation; the FLMs will consider such information in making their decision. The decision thresholds parallel the FLM levels of concern. For near field situations where a section of the atmosphere is polluted and is viewed against a scenic background, screening analysis values of contrast with an absolute value less than 0.05 ($|C| < 0.05$) would not likely result in an objection by the FLM. Similarly, a value of $\Delta E < 2$ from a screening analysis would not likely result in an objection. If a refined near field analysis is performed, values of $|C| < 0.02$ or $\Delta E < 1$ would not likely result in an objection by the FLM.

For distant or multi-source situations, if a cumulative visibility analysis has not previously been conducted and is not required for other analyses, a single-source change in extinction less than 5% would not generally trigger a need for a cumulative analysis. Under those circumstances, the FLM would not likely object to the proposed action. If the forecast single-source contribution to extinction is between 5% and 10%, or if a cumulative analyses is required or already exists, a special decision threshold applies. If the visibility impairment from the proposed action, in combination with cumulative new source growth, is less than a change in extinction of 10% for all time periods, the FLMs will not likely object to the proposed action. If the visibility impairment

[*] The *de minimis* level of 0.4% is defined as 4% of the unacceptable change in extinction (*i.e.*, 10%), paralleling the discussion of significant impact levels in the proposed new source review modifications. (FR 61 38291-38293)

from the proposed action, in combination with cumulative new source growth, is greater than or equal to a change in extinction of 10% for any time periods, the FLMs will likely object to the proposed action, unless the contribution from the proposed action is less than a *de minimis* value of 0.4% for these time periods.

Relationship to Regional Haze Rule

The FLAG recommendations are complimentary to the regional haze rule. However, the visibility recommendations of FLAG are intended for new source review and NEPA type applications, whereas the regional haze rule addresses the effects of existing sources of visibility impairment in conjunction with new source review. The FLAG recommendation is designed to prevent new sources from causing visibility impairment, and the criteria for developing these recommendations do not necessarily apply to existing sources. At the time of this writing, new source review is an ongoing effort, but it will be several years before State Implementation Plans (SIPs) under the regional haze rule are submitted. If the new visibility SIPs adequately account for new source growth, the FLMs may reconsider the FLAG recommendations.

The visibility parameters for cumulative impact analysis, outlined here, are related to those in the regional haze rule. However, an assumption inherent in regional haze is that the pollution is fairly evenly distributed over a broad geographic extent. By contrast, the analysis techniques, described herein, at most deal with the aggregation of a subset of the plumes that might affect regional haze, but do not meet the criteria of being a regional haze.

The levels of concern and *de minimis* levels described in this document were arrived at, in part, with the knowledge they apply to a limited number of sources under new source review and that the analyses are always compared to natural conditions. The *de minimis* levels described here should not be used for determining whether emissions from an existing source are reasonably anticipated to cause or contribute to visibility impairment. Those criteria have been laid out in the regulations (40 CFR §51 Subpart P Protection of Visibility) and through interpretations of those regulations by EPA and courts.

While there are some distinct differences between this document and the regional haze rule, there are also some similarities. One of these is the need for conducting a cumulative assessment of visibility impairment. This will include the need for evaluating the effects of sources beyond an individual state's boundaries. Therefore, it is anticipated that when modeling centers are established for SIP development work, the tools they use may be applicable to analyzing both existing impairment as well as the potential impacts of new source growth.

b. Analysis Techniques

There are two fundamentally different approaches one could adopt to determine visibility impairment. One is a technically rigorous, complex, and situation-specific method, while the other is a more generalized approach. The more rigorous approach requires determination of particle concentrations and size distributions, calculation of particle growth dynamics, and application of Mie Theory to determine the optical characteristics of the aerosol distribution. Sophisticated radiative transfer models are then applied, using aerosol optical characteristics, lighting and scene characteristics, and spatial distribution of the pollutants to calculate the path and wavelength of image-forming and non-image-forming light that reaches a specific observer from all points in the scene being viewed.

While such a detailed analysis may be useful for assessing specific cases, it is usually impractical for situations in which visibility could be experienced in a nearly infinite variety of circumstances. Practical limitations frequently dictate that it is more reasonable to use a generalized approach to determine the change in extinction by using bulk-averaged aerosol-specific extinction efficiencies rather than trying to reproduce the complex optical phenomena that may occur in the atmosphere.

Consequently, FLAG recommends the generalized approach for determining the effects on visibility from a proposed new source's emissions. The procedure is to estimate the atmospheric concentrations of visibility impairing pollutants, apply representative visibility parameters, calculate the change from specified reference levels, and compare this change with prescribed threshold values.

FLAG is using estimates of natural conditions as reference levels for Class I visibility analyses. Comparison with natural conditions will help ensure that those conditions will not be impaired in keeping with Section 169A of the CAA. Because of the different requirements of the two modeling approaches discussed below, natural conditions must be expressed using two different metrics:

- Standard visual range (visual range adjusted to a Rayleigh condition of 10 Mm^{-1}), for near field modeling. Present EPA guideline visibility models traditionally accept visibility conditions expressed in these terms.

- Extinction, for distant/multi-source modeling. Visibility conditions should be expressed in terms of the averaged extinction efficiencies of the individual atmospheric constituents that comprise the total extinction. The relative humidity effects of the hygroscopic particles must be accounted for when the change in extinction is calculated.

Information needed to calculate the above indices is provided in Appendix 2.B for all 156 Class I areas for which visibility is an important attribute. If estimates are needed for Class II areas, the FLM can provide them.

c. Air Quality Models and Visibility Assessment Procedures

The modeling discussion will be divided into two parts to address the very different requirements for 1) near field modeling where plumes or layers are compared against a viewing background and 2) distant/multi-source modeling for plumes and aggregations of plumes that affect the general

appearance of a scene. Note that both of the above analyses might apply depending on the source's proximity to all portions of the Class I area or multiple Class I areas.

Near Field Analysis Technique for Analyzing Plumes or Layers Viewed Against a Background

The Model (Near Field – Steady State Conditions Applicable)

EPA has recommended a methodology to assess impacts due to coherent plumes. A guideline, for when these steady state conditions apply, is the distance from the source to the view of concern. This technique is usually applied for sources locating less than 50 km from a Class I area. Applicants must model their potential plume impacts using the screening model, VISCREEN (USEPA, 1992a), or, if the next level of analysis is called for, PLUVUE II (USEPA 1992b and 1996c). Both of these models use steady-state, gaussian-based plume dispersion techniques to calculate one-hour concentrations within an elevated plume. These two models calculate the change in the color difference index (ΔE) and contrast between the plume and the viewing background. Values of ΔE and plume contrast are based on the concentrations of fine primary particulates (including sulfates), nitrogen dioxide (NO_2), and the geometry of the observer, target, plume, and the position of the sun. PLUVUE II also allows consideration of the effects of secondarily formed sulfates. Plume contrast results from an increase or decrease in light transmitted from the viewing background through the plume to the observer. The specifics of the emission scenarios and plume/observer geometries for modeling should be selected in consultation with the appropriate FLM. At the present time there is no recommended procedure for conducting analyses of multiple sources with these modeling tools, so multiple coherent plumes must be treated individually, or combined into a representative single source if reasonable.

The Recommended Prescription (Near Field – Steady State Conditions)

Until better modeling tools are available, FLAG recommends using the present EPA techniques for plume visual impact screening analyses (USEPA 1992a). However, unlike those procedures, which suggest the use of current average annual visibility conditions, FLAG recommends that the visual range corresponding to natural conditions be used to generate the hourly estimates of ΔE and plume contrast. FLAG recommends this change in order for the analysis technique to be consistent with the national visibility goal. For screening-level analyses, FLAG recommends the use of the annual average reconstructed natural conditions given in the last column in Table 2.B-1 in Appendix 2.B. The table entry gives the specified reference level (including the effects of relative humidity) expressed in Mm^{-1}. The conversion to standard visual range can be made using Equation 1 in Appendix 2.A. For the refined analyses, the reconstructed natural condition is derived from the relative humidity used in the modeling, the corresponding relative humidity adjustment factor (Table 2.A-1), and estimated natural aerosol concentrations (Table 2.B-1).

If a screening analysis of a new or modified source can demonstrate that its emissions will not cause a plume with any hourly estimates of ΔE greater than or equal to 2.0, or the absolute value of the contrast values ($|C|$) greater than or equal to 0.05, the FLM is not likely to object to the issuance of the PSD permit based on near field visibility impacts and no further near field visibility analyses will be requested. More refined analyses (*i.e.*, PLUVUE II) would be undertaken if the above conditions are not met and would be compared against lower levels of concern; the FLM would not likely object if $\Delta E < 1.0$ and $|C| < 0.02$.

If the estimated plume parameters exceed the aforementioned values, the FLM would rely on a case-by-case effects-based test (NPS 1993), taking into account magnitude, frequency, duration, and other factors, to decide whether to make an adverse impact determination.

Distant/Multi-Source Techniques for Analyzing Whether a Plume or an Aggregation of Plumes Alters the General Appearance of a Scene

This application is generally more complex than the near field, coherent plume modeling analyses and the guidance from EPA is less definitive, though it is evolving. The modeling system must include the capability to assess single and multiple sources in a temporally and spatially varying meteorological domain, accommodate modeling domains measuring hundreds of kilometers, include rough and complex terrain, provide pollutant concentration estimates for averaging times from one-hour to annual, and address inert and secondarily formed pollutants and dry and wet deposition. In the early 1990s the FLMs and the EPA recognized the need for a consistent, technically credible technique to estimate contributions to air quality of multiple new sources locating more than 50 km from Class I areas. Toward that end, the Interagency Workgroup on Air Quality Modeling (IWAQM) was established to develop a modeling protocol for this application. FLAG proposes to rely on the IWAQM recommendations and modeling guidance for long range pollutant transport (present guidance, USEPA 1998[*]). This technique is usually applied when sources are located more than 50 kilometers from portions of a Class I area, when an aggregation of plumes may impact an area, or when the assumptions inherent in steady state visibility models do not apply.

The Model (Distant/Multi-Source)

Revised IWAQM guidance (USEPA 1998[*]) recommends non-steady state air quality modeling systems for screening and refined analyses. The IWAQM recommendations are adaptations and refinements of the CALPUFF dispersion modeling system, including the CALMET meteorological model (USEPA 1996a, http://www.src.com/calpuff/calpuff1.htm). This modeling system consists of diagnostic meteorological models, a gaussian puff dispersion model with algorithms for chemical transformation, wet and dry deposition, and complex terrain, and a post processor (CALPOST) for calculating concentration and deposition fields and visibility impacts.

The modeling systems/techniques outlined in this recommendation provide ground level concentrations of visibility impairing pollutants. These concentrations can then be used to calculate the extinction due to these pollutants, using the relationships outlined in Appendix 2.A. The results should be compared against a reference level derived from aerosol information (relative humidity adjusted hygroscopic and non-hygroscopic concentrations plus Rayleigh extinction) given in Appendix 2.B for each Class I area. This reference level is a function of relative humidity. To achieve the best temporal and spatial resolution, relative humidity data included in the meteorological data base of the air quality model and the data provided in Table 2.A-1 is the preferred basis for making the necessary calculation of the relative humidity adjustment term f(RH) for refined visibility analyses. The approach, for screening level analyses, is to use the quarterly averaged reference levels given in Table 2.B-1 that are based on spatially interpolated seasonal relative humidity values and empirically derived f(RH) adjustment factors (IMPROVE 2000). In

[*] At the time of this writing, USEPA is considering similar procedures for incorporation into the Guideline on Air Quality Models (40 CFR §51 Appendix W). This should be consulted for the latest information.

either approach, the same relative humidity adjustment factor, f(RH), is applied to determine both the reference level and the effect of the incremental increase associated with the new source(s). An example model application is given in Appendix 2.C.

For the purposes of the following prescription, FLAG recommends basing the analyses on block 24-hour averages (*i.e.*, daily) of modeled visibility. The 24-hour average was selected over the 1-hour average time because:

- Our confidence in model performance for 24-hours is higher than for shorter time periods.
- The combined visibility effect of emissions from multiple sources transported over long distances is better represented over 24-hours than for shorter time periods.
- It avoids detailed day/night visibility considerations.
- It avoids developing and implementing site-specific, complex visibility analytical methods that are not available at this time (see discussion under Analysis Techniques).

<u>The Recommended Prescription (Distant/Multi-Source)</u>

The FLMs are concerned with the cumulative effects of new source growth on visibility; cumulative analyses need to be conducted. The FLMs recognize, however, that few cumulative visibility analyses have been done, therefore, the following prescription is suggested. If a cumulative analysis has not been performed for an area and if a single project's visibility impairment, compared against natural conditions, is below certain analysis thresholds, then the FLMs are not likely to object to the project or ask that a cumulative analysis be performed before the project proceeds. If a cumulative analysis has already been done or if a cumulative analysis is required because of other considerations (*i.e.*, increment consumption, NEPA, or other AQRVs), or if the analysis thresholds are exceeded, then the impacts of the proposed project are expected to be considered as part of a cumulative visibility analysis.

The prescription is as follows:

1. Calculate the single-source contribution. Compare results with the distant/multi-source Decision Threshold.
   - Determine whether a cumulative analysis has been done for the Class I area(s) in question, and if it has been done, use the input files from the cumulative analysis to perform this step.

   - If the estimated increase in visibility impairment attributed to the proposed project is = 10%, compared against natural conditions, for at least one modeled day, then the FLM will consider the magnitude, frequency, duration, and other factors to assess the impact, but is likely to object to the issuance of the permit.

   - If the estimated increase in visibility impairment attributed to the proposed project is <10%, then the analysis should proceed to the next step (Note that if the single-source contribution is always <0.4%, no further analyses are required).

2. If a cumulative analysis does not exist, compare the single-source contribution with distant/multi-source Analysis Threshold and assess the need for a cumulative analysis.

- If a cumulative analysis does not exist, and if there are no other requirements for a cumulative analysis, and if a new or modified source can demonstrate that its contribution to a change in extinction is <5.0%, compared against natural conditions, for all days, then the FLM is not likely to object to the issuance of the PSD permit based on visibility impacts.

- If the single-source contribution to a change in extinction is = 5.0% or if a cumulative analysis already exists or is required for some other reason, then the analysis should proceed to the next step and estimate its contribution to cumulative impacts.

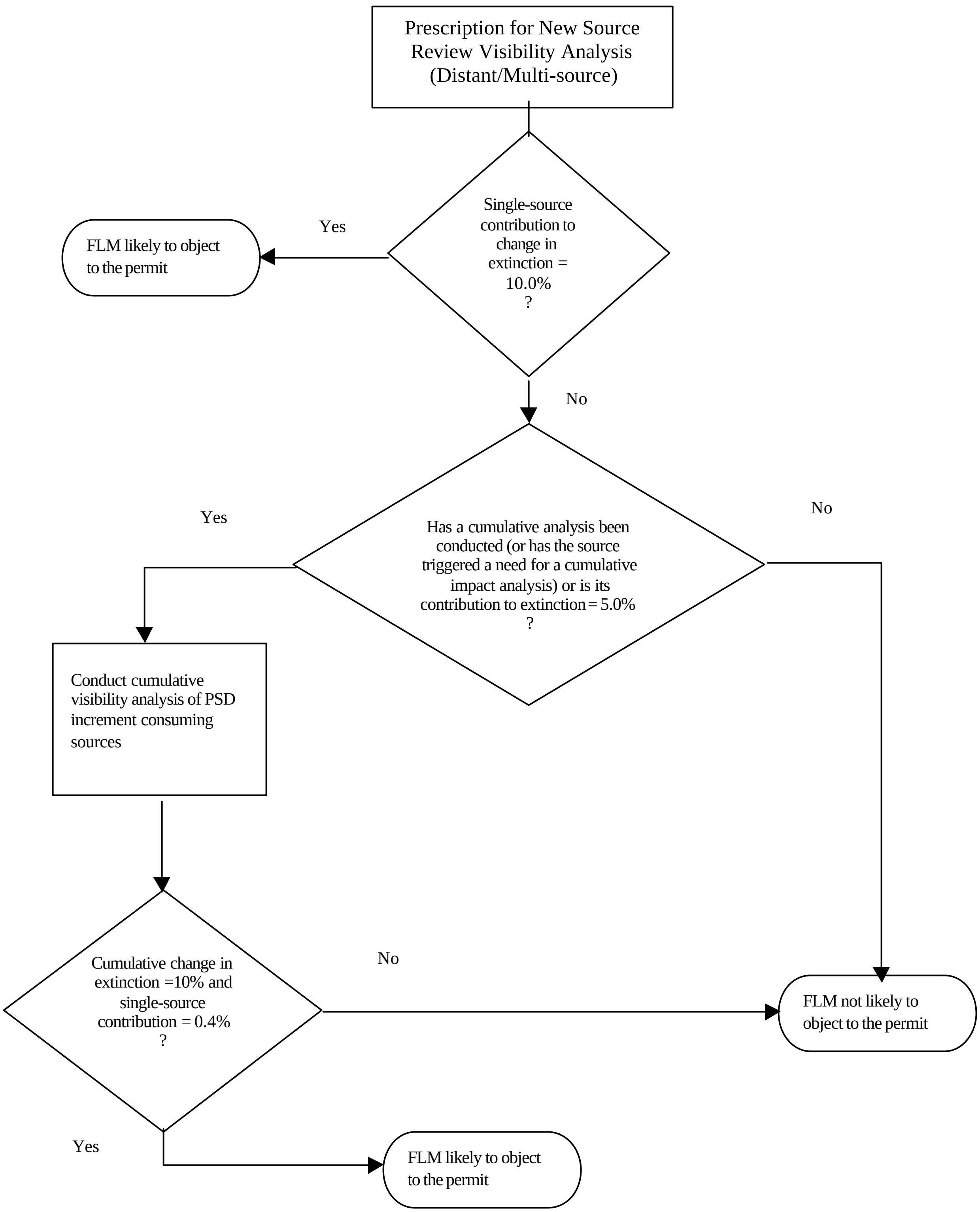
3. Conduct a cumulative analysis and compare results with cumulative, distant/multi-source Decision Threshold.

   - If cumulative change in extinction is =10%, for all modeled block 24-hour periods, and the new source contributes at least a 0.4% change in extinction to any of these periods, then the FLM will consider the magnitude, frequency, duration, and other factors to assess the impact, but is likely to object to the issuance of the permit.

   - If cumulative modeling results indicate that the effects from the combined sources are expected to cause a change in extinction that is < 10%, for all modeled block 24-hour periods, then the FLM is not likely to object to the issuance of the permit.

This prescription is portrayed schematically in Figure V-1.

Figure V-1. Prescription for visibility assessment for distant/multi-source applications (source greater than or equal to 50 km from the Class I area)



d. Summary

FLAG has provided guidance in the form of recommendations, specific prescriptions, and interpretation of results for assessing visibility impacts near Class I areas (although this guidance is generally applicable to Class II areas, as well). The guidance addresses assessments for sources proposed for locations near and at large distances from these areas. It also recommends impairment thresholds and identifies the conditions for which cumulative analyses of all increment-consuming sources would be necessary. The key components of the recommendations are highlighted below.

In general, FLAG recommends that an applicant:

- Consult with the appropriate regulatory agency and with the FLM for the affected Class I area(s) or other affected area for confirmation of preferred procedures and for the need for a cumulative analysis.

- Obtain FLM recommendation for the specified reference levels (estimate of natural conditions) and, if applicable, FLM recommended plume/observer geometries and model receptor locations.

- Apply the applicable EPA Guideline, steady-state models for regions within the Class I area that are affected by plumes or layers that are viewed against a background (generally within 50 km of the source).

  Calculate hourly estimates of ΔE and plume contrast, with respect to natural conditions, and compare these estimates with the thresholds given in Section D.2.c.

- For regions of the Class I area where visibility impairment from the source would cause a general alteration of the appearance of the scene (generally 50 km or more away from the source or from the interaction of the emissions from multiple sources), apply a non-steady-state air quality model with chemical transformation capabilities (refer to IWAQM guidance documents), which yields ambient concentrations of visibility-impairing pollutants. At each Class I receptor:

  Calculate the change in extinction due to the source being analyzed, compare these changes with the reference conditions, and compare these results with the thresholds given in Section D.2.c.

  If necessary, calculate the cumulative change in extinction due to new source growth.

Appendix 2.A
Visibility Parameters

Visibility is usually characterized by either visual range (VR) (the greatest distance that a large dark object can be seen) or by the light-extinction coefficient (b_{ext}) (the attenuation of light per unit distance due to scattering and absorption by gases and particles in the atmosphere) (IMPROVE, 1996). Under certain assumed conditions, these parameters are inversely related to each other by Equation 1; a long visual range corresponds to a low extinction. Visual range is useful for safety reasons such as to direct aircraft traffic near airports, but is not particularly useful for assessing the quality of scenic vistas. Nonetheless, visual range remains a useful measure for describing visibility, especially for communication with the general public. The dimensions of VR are length and the dimensions of b_{ext} are 1/length. Visual range is usually expressed in kilometers. The extinction coefficient is sometimes expressed as "inverse kilometers" (km^{-1}) or as "inverse megameters" (Mm^{-1}) (the reciprocal of 1 million meters). If b_{ext} is expressed in Mm^{-1} the coefficient 3.912 becomes 3912 as in Equation 1.

Equation 1. Relationship between visual range and light-extinction coefficient.

Other visibility parameters frequently used include ΔE and contrast. These metrics relate to the color difference or contrast, respectively, of a plume or haze with respect to some viewing background.

<u>Calculating the Extinction Coefficient</u>

Visibility is degraded by visible light scattered into and out of the line of sight and by light absorbed along the line of sight. Light extinction is the sum of light scattering and absorption, and is usually quantified using the light extinction coefficient (b_{ext}). Extinction can be measured directly or it can be calculated from representative aerosol measurements. Using a generalized approach to estimating visibility effects, one can calculate the extinction coefficient as the sum of its parts, *i.e.*, $b_{ext} = b_{scat} + b_{abs}$, where b_{scat} and b_{abs} are the light scattering and absorption coefficients. The light scattering and absorption coefficients can be further broken down by their respective components. The scattering coefficient is affected by light scattering (Rayleigh scattering (b_{Ray})) from air molecules and from particle scattering (b_{sp}); the particles can be natural aerosol or result from air pollutants. The absorption coefficient is affected by gaseous absorption (b is expressed in Mm aerosols (b_{OC}), and soil (b_{Soil}); the coarse scattering coefficient (b_{Coarse}) is not refined any further. Thus the particle scattering coefficient (b_{sp}) can be expressed as in Equation 2.

$$b_{sp} = b_{SO4} + b_{NO3} + b_{OC} + b_{Soil} + b_{Coarse}$$

Equation 2. Components of particle scattering.

Each of the particle scattering coefficients can be related to the mass of the components using the relationships in Equation 3.

$$\begin{aligned} b_{SO4} &= 3\left[(NH_4)_2SO_4\right]f(RH) \\ b_{NO3} &= 3\left[NH_4NO_3\right]f(RH) \\ b_{OC} &= 4\left[OC\right] \\ b_{Soil} &= 1\left[Soil\right] \\ b_{Coarse} &= 0.6\left[\text{Coarse Mass}\right] \end{aligned}$$

Equation 3. Relationship between particle scattering and mass of each species.

The quantities in brackets are the masses expressed in $\mu g/m^3$. (It is assumed that the forms of the $SO_4^{=}$ and NO_3^{-} are ammonium sulfate [$(NH_4)_2SO_4$] and ammonium nitrate [NH_4NO_3].) The numeric coefficients are the "dry" scattering efficiencies (m^2/g). The term f(RH) is the relative humidity adjustment factor. The extinction coefficients are in Mm^{-1}. If the "dry" scattering efficiencies are divided by 1000 (*i.e.*, 0.003 instead of 3) the resultant extinction coefficients will be in km^{-1}.

Particle absorption (b_{ap}) is primarily due to elemental carbon (soot). Similarly, absorption by gases (b_{ag}) is primarily from nitrogen dioxide (NO_2). For purposes of analyzing the effects of soot or NO_2 on visibility in a modeling analysis, the relationships in Equation 4 should be used. Again, the quantities in brackets are the masses of elemental carbon or nitrogen dioxide in $\mu g/m^3$ and 10 and 0.17 are the extinction efficiencies. Nitrogen dioxide absorption is usually only an issue in the near-field, therefore, it is usually not considered in an analysis for distant sources.

$$b_{ap} = 10[EC]$$

$$b_{ag} = 0.17[NO_2]$$

Equation 4. Relationship between particle absorption and elemental carbon.

The total atmospheric extinction can be expressed as in Equation 5, where b_{Ray} is the Rayleigh scattering component, which is assumed to be 10 Mm^{-1}.

$$b_{ext} = b_{SO4} + b_{NO3} + b_{OC} + b_{soil} + b_{Coarse} + b_{ap}\ (+\ b_{ag})^{*} + b_{Ray}$$

Equation 5. Components of Extinction (*b_{ag} is usually only considered in near-field analyses).

To the extent that a source contributes to the formation of some of these constituents, those contributions can be summed to yield the source's contribution to extinction. This will be discussed in more detail below.

Examination of Equation 3 reveals that the sulfate and nitrate components of the extinction coefficient are dependent upon relative humidity. These aerosols are hygroscopic and the addition of water enhances their scattering efficiencies. It is sometimes convenient to consider the sulfate and nitrate components of extinction separately from the remaining components of Equation 5 and to keep the relative humidity adjustment factor (f(RH)) separate. Equation 5 can then be rewritten as in Equation 6, where b_{hygro} is the combined extinction coefficient of sulfate and nitrate, excluding the relative humidity adjustment factor, and $b_{non\text{-}hygro}$ is the sum of b_{OC}, b_{Soil}, b_{Coarse}, b_{ap}, and b_{ag}.

$$b_{ext} = b_{hygro} f(RH) + b_{non\text{-}hygro} + b_{Ray}$$

Equation 6. Extinction coefficient expressed as the sulfate and nitrate contribution ($b_{hygro} = 3[(NH_4)_2SO_4 + NH_4NO_3]$) and non-hygroscopic components ($b_{non\text{-}hygro} = b_{OC} + b_{Soil} + b_{Coarse} + b_{ap} + b_{ag}$).

The relative humidity adjustment factor requires some further explanation. The variation of the effect of relative humidity on the extinction efficiency, f(RH), of sulfates and nitrates is given numerically in Table 2.B-1. As can be seen, the effect of relative humidity on the extinction efficiency of these aerosols is non-linear, and is several times greater at higher relative humidity than at lower humidity.

FLAG proposes that the relative humidity adjustment to the "dry" scattering efficiencies (unadjusted for relative humidity) for hygroscopic particles are made as follow:

- The preferred alternative is to apply day-by-day f(RH) adjustment factors to the analysis. For this alternative hourly relative humidity data are needed. Hourly f(RH) values should be averaged to generate a 24-hour relevant f(RH) factor. FLAG recommends, however, that if the hourly relative humidity exceeds 98%, that it be rolled back to 98%, so that there will be no f(RH) factors applied that are greater than f(98).

- For screening analyses the adjustment factor can be based on historic averages of f(RH) for the Class I area(s) of concern (Table 2.B-1).

Table 2.A-1. f(RH) values for various values of relative humidity*

RH(%)	f(RH)	RH(%)	f(RH)	RH(%)	f(RH)	RH(%)	f(RH)
1	1.0	26	1.0	51	1.2	76	2.3
2	1.0	27	1.0	52	1.3	77	2.4
3	1.0	28	1.0	53	1.3	78	2.5
4	1.0	29	1.0	54	1.3	79	2.6
5	1.0	30	1.0	55	1.3	80	2.7
6	1.0	31	1.0	56	1.3	81	2.8
7	1.0	32	1.0	57	1.3	82	3.0
8	1.0	33	1.0	58	1.4	83	3.1
9	1.0	34	1.0	59	1.4	84	3.2
10	1.0	35	1.0	60	1.4	85	3.4
11	1.0	36	1.0	61	1.5	86	3.6
12	1.0	37	1.1	62	1.5	87	3.8
13	1.0	38	1.1	63	1.5	88	4.0
14	1.0	39	1.1	64	1.6	89	4.4
15	1.0	40	1.1	65	1.7	90	4.7
16	1.0	41	1.1	66	1.7	91	5.3
17	1.0	42	1.1	67	1.7	92	5.9
18	1.0	43	1.1	68	1.8	93	7.0
19	1.0	44	1.2	69	1.9	94	8.4
20	1.0	45	1.2	70	1.9	95	9.8
21	1.0	46	1.2	71	2.0	96	12.4
22	1.0	47	1.2	72	2.0	97	15.1
23	1.0	48	1.2	73	2.1	98	18.1
24	1.0	49	1.2	74	2.1	99	18.1♦
25	1.0	50	1.2	75	2.2	100	18.1♦

* The values in Table 2.A-1 are only appropriate for averaging times of 1 hour or less.

♦ The values for 99% and 100% RH are rolled back to the value for 98%.

Appendix 2.B
Estimate of Natural Conditions

Table 2.B-1 provides natural background estimates for visibility reference levels for each Class I area; these will serve until better estimates of natural conditions are available. The estimates for natural background aerosol concentrations provided in the State of Science and Technology No.24 (NAPAP, 1990), shown in Table 2.B-2 provide the basis for these estimates. The seasonal and annual means for the relative humidity adjustment factor f(RH) given in the table are computed using spatially interpolated and quarterly averaged National Weather Service relative humidity data and the following empirical relationships derived from site-specific relative humidity collected at some Class I areas (IMPROVE 2000).

$$f(RH) = 0.34 + 0.59(1/(1-RH)) + 0.09(1/(1-RH))^2 \qquad \text{(Annual)}$$

$$f(RH) = 0.35 + 0.82(1/(1-RH)) \qquad \text{(Winter)}$$

$$f(RH) = -0.01 + 0.78(1/(1-RH)) + 0.08(1/(1-RH))^2 \qquad \text{(Spring)}$$

$$f(RH) = -0.19 + 0..99(1/(1-RH)) \qquad \text{(Summer)}$$

$$f(RH) = -0.25 + 1.02(1/(1-RH)) + 0.01(/(1-RH))^2 \qquad \text{(Fall)}$$

For annual, winter (Dec, Jan, Feb), spring (Mar, Apr, May), summer (Jun, July, Aug), and fall (Sep, Oct, Nov), respectively. The visibility impairment (b_{ext}) due to this assumed distribution of background aerosol is calculated using Equation 6, Appendix 2.A.

The source of the relative humidity data is 10 years of monthly averaged historic National Weather Service data (over 250 sites) spatially interpolated and gridded (0.25 degree grid size) and further interpolated to specific Class I areas. The annual and quarterly means are shown in Figure 2.B-1.

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	**Non Hygro**	**Rayleigh**			
Acadia NP	Annual	0.9	8.5	10.0	3.0	11.2	21.2
	Winter	0.9	8.5	10.0	2.9	11.1	21.1
	Spring	0.9	8.5	10.0	2.8	11.0	21.0
	Summer	0.9	8.5	10.0	3.2	11.4	21.4
	Fall	0.9	8.5	10.0	3.1	11.3	21.3
Agua Tibia W	Annual	0.6	4.5	10.0	2.5	6.0	16.0
	Winter	0.6	4.5	10.0	2.4	5.9	15.9
	Spring	0.6	4.5	10.0	2.6	6.1	16.1
	Summer	0.6	4.5	10.0	2.5	6.0	16.0
	Fall	0.6	4.5	10.0	2.3	5.9	15.9
Alpine Lakes W	Annual	0.6	4.5	10.0	3.7	6.7	16.7
	Winter	0.6	4.5	10.0	4.5	7.2	17.2
	Spring	0.6	4.5	10.0	3.3	6.5	16.5
	Summer	0.6	4.5	10.0	2.7	6.1	16.1
	Fall	0.6	4.5	10.0	5.1	7.6	17.6
Anaconda – Pintlar W	Annual	0.6	4.5	10.0	2.5	6.0	16.0
	Winter	0.6	4.5	10.0	3.7	6.7	16.7
	Spring	0.6	4.5	10.0	2.3	5.9	15.9
	Summer	0.6	4.5	10.0	1.8	5.6	15.6
	Fall	0.6	4.5	10.0	3.1	6.4	16.4
Ansel Adams W	Annual	0.6	4.5	10.0	2.0	5.7	15.7
	Winter	0.6	4.5	10.0	3.0	6.3	16.3
	Spring	0.6	4.5	10.0	1.7	5.5	15.5
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	2.2	5.8	15.8
Arches NP	Annual	0.6	4.5	10.0	1.9	5.6	15.6
	Winter	0.6	4.5	10.0	3.3	6.5	16.5
	Spring	0.6	4.5	10.0	1.5	5.4	15.4
	Summer	0.6	4.5	10.0	1.4	5.3	15.3
	Fall	0.6	4.5	10.0	2.3	5.9	15.9
Badlands NP (W)	Annual	0.6	4.5	10.0	2.6	6.1	16.1
	Winter	0.6	4.5	10.0	3.1	6.4	16.4
	Spring	0.6	4.5	10.0	2.6	6.1	16.1
	Summer	0.6	4.5	10.0	2.2	5.8	15.8
	Fall	0.6	4.5	10.0	2.8	6.2	16.2

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
Bandelier NM (W)	Annual	0.6	4.5	10.0	1.8	5.6	15.6
	Winter	0.6	4.5	10.0	2.3	5.9	15.9
	Spring	0.6	4.5	10.0	1.5	5.4	15.4
	Summer	0.6	4.5	10.0	1.7	5.5	15.5
	Fall	0.6	4.5	10.0	2.0	5.7	15.7
Big Bend NP	Annual	0.6	4.5	10.0	2.1	5.8	15.8
	Winter	0.6	4.5	10.0	2.3	5.9	15.9
	Spring	0.6	4.5	10.0	1.9	5.6	15.6
	Summer	0.6	4.5	10.0	2.2	5.8	15.8
	Fall	0.6	4.5	10.0	2.2	5.8	15.8
Black Canyon NP	Annual	0.6	4.5	10.0	1.9	5.6	15.6
	Winter	0.6	4.5	10.0	2.7	6.1	16.1
	Spring	0.6	4.5	10.0	1.6	5.5	15.5
	Summer	0.6	4.5	10.0	1.6	5.5	15.5
	Fall	0.6	4.5	10.0	2.2	5.8	15.8
Bob Marshall W	Annual	0.6	4.5	10.0	2.7	6.1	16.1
	Winter	0.6	4.5	10.0	3.9	6.8	16.8
	Spring	0.6	4.5	10.0	2.5	6.0	16.0
	Summer	0.6	4.5	10.0	2.0	5.7	15.7
	Fall	0.6	4.5	10.0	3.5	6.6	16.6
Bosque del Apache W	Annual	0.6	4.5	10.0	1.7	5.5	15.5
	Winter	0.6	4.5	10.0	2.2	5.8	15.8
	Spring	0.6	4.5	10.0	1.3	5.3	15.3
	Summer	0.6	4.5	10.0	1.7	5.5	15.5
	Fall	0.6	4.5	10.0	1.8	5.6	15.6
Boundary Waters Canoe Area W	Annual	0.9	8.5	10.0	3.3	11.5	21.5
	Winter	0.9	8.5	10.0	3.6	11.7	21.7
	Spring	0.9	8.5	10.0	2.6	10.8	20.8
	Summer	0.9	8.5	10.0	3.4	11.6	21.6
	Fall	0.9	8.5	10.0	3.9	12.0	22.0
Breton Island W	Annual	0.9	8.5	10.0	3.8	11.9	21.9
	Winter	0.9	8.5	10.0	3.4	11.6	21.6
	Spring	0.9	8.5	10.0	4.0	12.1	22.1
	Summer	0.9	8.5	10.0	4.1	12.2	22.2
	Fall	0.9	8.5	10.0	3.6	11.7	21.7

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
Bridger W	Annual	0.6	4.5	10.0	2.1	5.7	15.7
	Winter	0.6	4.5	10.0	2.9	6.2	16.2
	Spring	0.6	4.5	10.0	1.9	5.6	15.6
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	2.4	5.9	15.9
Brigantine W	Annual	0.9	8.5	10.0	3.0	11.2	21.2
	Winter	0.9	8.5	10.0	2.8	11.0	21.0
	Spring	0.9	8.5	10.0	2.9	11.1	21.1
	Summer	0.9	8.5	10.0	3.4	11.5	21.5
	Fall	0.9	8.5	10.0	3.0	11.2	21.2
Bryce Canyon NP	Annual	0.6	4.5	10.0	1.8	5.6	15.6
	Winter	0.6	4.5	10.0	2.7	6.1	16.1
	Spring	0.6	4.5	10.0	1.4	5.4	15.4
	Summer	0.6	4.5	10.0	1.4	5.3	15.3
	Fall	0.6	4.5	10.0	2.0	5.7	15.7
Cabinet Mountains W	Annual	0.6	4.5	10.0	2.7	6.1	16.1
	Winter	0.6	4.5	10.0	4.2	7.0	17.0
	Spring	0.6	4.5	10.0	2.4	5.9	15.9
	Summer	0.6	4.5	10.0	1.9	5.7	15.7
	Fall	0.6	4.5	10.0	3.8	6.8	16.8
Caney Creek W	Annual	0.9	8.5	10.0	3.1	11.3	21.3
	Winter	0.9	8.5	10.0	3.1	11.3	21.3
	Spring	0.9	8.5	10.0	3.3	11.5	21.5
	Summer	0.9	8.5	10.0	3.0	11.2	21.2
	Fall	0.9	8.5	10.0	3.1	11.3	21.3
Canyonlands NP	Annual	0.6	4.5	10.0	1.9	5.6	15.6
	Winter	0.6	4.5	10.0	3.2	6.4	16.4
	Spring	0.6	4.5	10.0	1.5	5.4	15.4
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	2.3	5.9	15.9
Cape Romain W	Annual	0.9	8.5	10.0	3.3	11.5	21.5
	Winter	0.9	8.5	10.0	2.9	11.1	21.1
	Spring	0.9	8.5	10.0	3.3	11.4	21.4
	Summer	0.9	8.5	10.0	3.9	12.0	22.0
	Fall	0.9	8.5	10.0	3.3	11.5	21.5

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
Capitol Reef NP	Annual	0.6	4.5	10.0	1.9	5.6	15.6
	Winter	0.6	4.5	10.0	3.0	6.3	16.3
	Spring	0.6	4.5	10.0	1.5	5.4	15.4
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	2.2	5.8	15.8
Caribou W	Annual	0.6	4.5	10.0	2.3	5.9	15.9
	Winter	0.6	4.5	10.0	3.6	6.6	16.6
	Spring	0.6	4.5	10.0	2.0	5.7	15.7
	Summer	0.6	4.5	10.0	1.7	5.5	15.5
	Fall	0.6	4.5	10.0	2.7	6.1	16.1
Carlsbad Caverns NP	Annual	0.6	4.5	10.0	1.8	5.6	15.6
[redacted]							
	Spring	0.6	4.5	10.0	1.5	5.4	15.4
	Summer	0.6	4.5	10.0	1.9	5.6	15.6
	Fall	0.6	4.5	10.0	1.8	5.6	15.6
Chassahowitzka W	Annual	0.9	8.5	10.0	3.9	12.0	22.0
	Winter	0.9	8.5	10.0	3.4	11.6	21.6
	Spring	0.9	8.5	10.0	3.7	11.8	21.8
	Summer	0.9	8.5	10.0	4.1	12.2	22.2
	Fall	0.9	8.5	10.0	3.9	12.0	22.0
Chiricahua NM (W)	Annual	0.6	4.5	10.0	1.6	5.4	15.4
	Winter	0.6	4.5	10.0	2.1	5.8	15.8
	Spring	0.6	4.5	10.0	1.2	5.2	15.2
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	1.6	5.5	15.5
Chiricahua W	Annual	0.6	4.5	10.0	1.5	5.4	15.4
	Winter	0.6	4.5	10.0	2.1	5.7	15.7
	Spring	0.6	4.5	10.0	1.2	5.2	15.2
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	1.6	5.5	15.5
Cohutta W	Annual	0.9	8.5	10.0	3.2	11.4	21.4
	Winter	0.9	8.5	10.0	3.0	11.2	21.2
	Spring	0.9	8.5	10.0	3.1	11.3	21.3
	Summer	0.9	8.5	10.0	3.6	11.7	21.7
	Fall	0.9	8.5	10.0	3.3	11.4	21.4

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
Crater Lake NP	Annual	0.6	4.5	10.0	3.3	6.5	16.5
	Winter	0.6	4.5	10.0	4.7	7.3	17.3
	Spring	0.6	4.5	10.0	3.1	6.4	16.4
	Summer	0.6	4.5	10.0	2.2	5.8	15.8
	Fall	0.6	4.5	10.0	4.4	7.2	17.2
Craters of the Moon NM (W)	Annual	0.6	4.5	10.0	2.2	5.8	15.8
	Winter	0.6	4.5	10.0	3.8	6.8	16.8
	Spring	0.6	4.5	10.0	1.9	5.7	15.7
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	2.8	6.2	16.2
Cucamonga W	Annual	0.6	4.5	10.0	2.3	5.9	15.9
	Winter	0.6	4.5	10.0	2.4	5.9	15.9
	Spring	0.6	4.5	10.0	2.3	5.9	15.9
	Summer	0.6	4.5	10.0	2.2	5.8	15.8
	Fall	0.6	4.5	10.0	2.2	5.8	15.8
Desolation W	Annual	0.6	4.5	10.0	2.1	5.7	15.7
	Winter	0.6	4.5	10.0	3.3	6.5	16.5
	Spring	0.6	4.5	10.0	1.8	5.6	15.6
	Summer	0.6	4.5	10.0	1.6	5.4	15.4
	Fall	0.6	4.5	10.0	2.4	6.0	16.0
Diamond Peak W	Annual	0.6	4.5	10.0	3.5	6.6	16.6
	Winter	0.6	4.5	10.0	4.9	7.4	17.4
	Spring	0.6	4.5	10.0	3.2	6.4	16.4
	Summer	0.6	4.5	10.0	2.3	5.9	15.9
	Fall	0.6	4.5	10.0	4.8	7.4	17.4
Dolly Sods W	Annual	0.9	8.5	10.0	3.1	11.3	21.3
	Winter	0.9	8.5	10.0	3.0	11.2	21.2
	Spring	0.9	8.5	10.0	3.0	11.2	21.2
	Summer	0.9	8.5	10.0	3.4	11.6	21.6
	Fall	0.9	8.5	10.0	3.2	11.4	21.4
Dome Land W	Annual	0.6	4.5	10.0	1.9	5.7	15.7
	Winter	0.6	4.5	10.0	2.4	6.0	16.0
	Spring	0.6	4.5	10.0	1.7	5.5	15.5
	Summer	0.6	4.5	10.0	1.6	5.5	15.5
	Fall	0.6	4.5	10.0	2.1	5.7	15.7

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
Eagle Cap W	Annual	0.6	4.5	10.0	2.5	6.0	16.0
	Winter	0.6	4.5	10.0	4.3	7.1	17.1
	Spring	0.6	4.5	10.0	2.2	5.8	15.8
	Summer	0.6	4.5	10.0	1.6	5.5	15.5
	Fall	0.6	4.5	10.0	3.5	6.6	16.6
Eagles Nest W	Annual	0.6	4.5	10.0	2.0	5.7	15.7
	Winter	0.6	4.5	10.0	2.5	6.0	16.0
	Spring	0.6	4.5	10.0	1.9	5.6	15.6
	Summer	0.6	4.5	10.0	1.7	5.5	15.5
	Fall	0.6	4.5	10.0	2.2	5.8	15.8
Emigrant W	Annual	0.6	4.5	10.0	2.0	5.7	15.7
	Winter	0.6	4.5	10.0	3.2	6.4	16.4
	Spring	0.6	4.5	10.0	1.7	5.5	15.5
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	2.3	5.9	15.9
Everglades NP	Annual	0.9	8.5	10.0	3.9	12.0	22.0
	Winter	0.9	8.5	10.0	3.6	11.8	21.8
	Spring	0.9	8.5	10.0	3.7	11.9	21.9
	Summer	0.9	8.5	10.0	3.8	12.0	22.0
	Fall	0.9	8.5	10.0	4.0	12.1	22.1
Fitzpatrick W	Annual	0.6	4.5	10.0	2.1	5.7	15.7
	Winter	0.6	4.5	10.0	2.9	6.2	16.2
	Spring	0.6	4.5	10.0	1.9	5.7	15.7
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	2.4	6.0	16.0
Flat Tops W	Annual	0.6	4.5	10.0	2.0	5.7	15.7
	Winter	0.6	4.5	10.0	2.6	6.1	16.1
	Spring	0.6	4.5	10.0	1.8	5.6	15.6
	Summer	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Spring

0.6

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
Gates of the Mountains W	Annual	0.6	4.5	10.0	2.4	5.9	15.9
	Winter	0.6	4.5	10.0	3.1	6.4	16.4
	Spring	0.6	4.5	10.0	2.3	5.9	15.9
	Summer	0.6	4.5	10.0	1.8	5.6	15.6
	Fall	0.6	4.5	10.0	2.8	6.2	16.2
Gearhart Mountain W	Annual	0.6	4.5	10.0	2.5	6.0	16.0
	Winter	0.6	4.5	10.0	4.0	6.9	16.9
	Spring	0.6	4.5	10.0	2.3	5.9	15.9
	Summer	0.6	4.5	10.0	1.8	5.6	15.6
	Fall	0.6	4.5	10.0	3.2	6.4	16.4
Gila W	Annual	0.6	4.5	10.0	1.7	5.5	15.5
	Winter	0.6	4.5	10.0	2.2	5.8	15.8
	Spring	0.6	4.5	10.0	1.3	5.3	15.3
	Summer	0.6	4.5	10.0	1.6	5.5	15.5
	Fall	0.6	4.5	10.0	1.8	5.6	15.6
Glacier NP	Annual	0.6	4.5	10.0	2.8	6.2	16.2
	Winter	0.6	4.5	10.0	2.8	6.2	16.2
	Spring	0.6	4.5	10.0	2.5	6.0	16.0
	Summer	0.6	4.5	10.0	2.1	5.8	15.8
	Fall	0.6	4.5	10.0	3.8	6.8	16.8
Glacier Peak W	Annual	0.6	4.5	10.0	3.8	6.8	16.8
	Winter	0.6	4.5	10.0	4.4	7.2	17.2
	Spring	0.6	4.5	10.0	3.4	6.5	16.5
	Summer	0.6	4.5	10.0	2.8	6.2	16.2
	Fall	0.6	4.5	10.0	5.1	7.6	17.6
Goat Rocks W	Annual	0.6	4.5	10.0	3.6	6.6	16.6
	Winter	0.6	4.5	10.0	4.6	7.3	17.3
	Spring	0.6	4.5	10.0	3.2	6.4	16.4
	Summer	0.6	4.5	10.0	2.5	6.0	16.0
	Fall	0.6	4.5	10.0	5.0	7.5	17.5
Grand Canyon NP	Annual	0.6	4.5	10.0	1.6	5.5	15.5
	Winter	0.6	4.5	10.0	2.4	5.9	15.9
	Spring	0.6	4.5	10.0	1.3	5.3	15.3
	Summer	0.6	4.5	10.0	1.4	5.3	15.3
	Fall	0.6	4.5	10.0	1.7	5.5	15.5

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
Grand Teton NP	Annual	0.6	4.5	10.0	2.1	5.8	15.8
	Winter	0.6	4.5	10.0	3.0	6.3	16.3
	Spring	0.6	4.5	10.0	2.0	5.7	15.7
	Summer	0.6	4.5	10.0	1.6	5.5	15.5
	Fall	0.6	4.5	10.0	2.5	6.0	16.0
Great Gulf W	Annual	0.9	8.5	10.0	3.0	11.2	21.2
	Winter	0.9	8.5	10.0	2.8	11.0	21.0
	Spring	0.9	8.5	10.0	2.8	11.0	21.0
	Summer	0.9	8.5	10.0	3.3	11.5	21.5
	Fall	0.9	8.5	10.0	3.1	11.3	21.3
Great Sand Dunes NM (W)	Annual	0.6	4.5	10.0	2.0	5.7	15.7
	Winter	0.6	4.5	10.0	2.3	5.9	15.9
	Spring	0.6	4.5	10.0	1.7	5.5	15.5
	Summer	0.6	4.5	10.0	1.8	5.6	15.6
	Fall	0.6	4.5	10.0	2.2	5.8	15.8
Great Smoky Mountains NP	Annual	0.9	8.5	10.0	3.2	11.4	21.4
	Winter	0.9	8.5	10.0	3.0	11.2	21.2
	Spring	0.9	8.5	10.0	3.1	11.3	21.3
	Summer	0.9	8.5	10.0	3.6	11.8	21.8
	Fall	0.9	8.5	10.0	3.2	11.4	21.4
Guadalupe Mountains NP	Annual	0.6	4.5	10.0	1.8	5.6	15.6
	Winter	0.6	4.5	10.0	2.1	5.8	15.8
	Spring	0.6	4.5	10.0	1.5	5.4	15.4
	Summer	0.6	4.5	10.0	1.9	5.6	15.6
	Fall	0.6	4.5	10.0	1.8	5.6	15.6
Hells Canyon W	Annual	0.6	4.5	10.0	2.5	6.0	16.0
	Winter	0.6	4.5	10.0	4.3	7.1	17.1
	Spring	0.6	4.5	10.0	2.2	5.8	15.8
	Summer	0.6	4.5	10.0	1.7	5.5	15.5
	Fall	0.6	4.5	10.0	3.5	6.6	16.6
Hercules Glades W	Annual	0.9	8.5	10.0	3.1	11.3	21.3
	Winter	0.9	8.5	10.0	3.2	11.4	21.4
	Spring	0.9	8.5	10.0	3.1	11.3	21.3
	Summer	0.9	8.5	10.0	3.2	11.4	21.4
	Fall	0.9	8.5	10.0	3.1	11.3	21.3

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
Hoover W	Annual	0.6	4.5	10.0	2.0	5.7	15.7
	Winter	0.6	4.5	10.0	3.1	6.4	16.4
	Spring	0.6	4.5	10.0	1.7	5.5	15.5
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	2.3	5.9	15.9
Isle Royale NP	Annual	0.9	8.5	10.0	3.5	11.6	21.6
	Winter	0.9	8.5	10.0	3.4	11.6	21.6
	Spring	0.9	8.5	10.0	2.8	11.0	21.0
	Summer	0.9	8.5	10.0	3.6	11.7	21.7
	Fall	0.9	8.5	10.0	4.1	12.2	22.2
James River Face W	Annual	0.9	8.5	10.0	3.0	11.2	21.2
	Winter	0.9	8.5	10.0	2.9	11.1	21.1
	Spring	0.9	8.5	10.0	3.0	11.2	21.2
	Summer	0.9	8.5	10.0	3.5	11.7	21.7
	Fall	0.9	8.5	10.0	3.0	11.2	21.2
Jarbidge W	Annual	0.6	4.5	10.0	2.0	5.7	15.7
	Winter	0.6	4.5	10.0	3.5	6.6	16.6
	Spring	0.6	4.5	10.0	1.7	5.5	15.5
	Summer	0.6	4.5	10.0	1.3	5.3	15.3
	Fall	0.6	4.5	10.0	2.4	6.0	16.0
John Muir W	Annual	0.6	4.5	10.0	2.0	5.7	15.7
	Winter	0.6	4.5	10.0	2.9	6.2	16.2
	Spring	0.6	4.5	10.0	1.7	5.5	15.5
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	2.2	5.8	15.8
Joshua Tree NM (W)	Annual	0.6	4.5	10.0	2.1	5.7	15.7
	Winter	0.6	4.5	10.0	2.3	5.9	15.9
	Spring	0.6	4.5	10.0	2.0	5.7	15.7
	Summer	0.6	4.5	10.0	2.0	5.7	15.7
	Fall	0.6	4.5	10.0	2.0	5.7	15.7
Joyce Kilmer Slickrock W	Annual	0.9	8.5	10.0	3.2	11.4	21.4
	Winter	0.9	8.5	10.0	3.0	11.2	21.2
	Spring	0.9	8.5	10.0	3.1	11.3	21.3
	Summer	0.9	8.5	10.0	3.6	11.7	21.7
	Fall	0.9	8.5	10.0	3.2	11.4	21.4

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nts of Dry n (Mm^{-1}) Rayleigh	f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
10.0	2.0	5.7	15.7
10.0	3.0	6.3	16.3
10.0	1.7	5.5	15.5
10.0	1.6	5.5	15.5
10.0	2.3	5.9	15.9
10.0	3.4	6.5	16.5
10.0	4.7	7.3	17.3
10.0	3.2	6.4	16.4
10.0	2.3	5.9	15.9
10.0	4.4	7.2	17.2
10.0	2.0	5.7	15.7
10.0	2.8	6.2	16.2
10.0	1.7	5.5	15.5
10.0	1.6	5.5	15.5
10.0	2.2	5.8	15.8
10.0	1.9	5.6	15.6
10.0	2.5	6.0	16.0
10.0	1.6	5.5	15.5
10.0	1.7	5.5	15.5
10.0	2.2	5.8	15.8
10.0	2.3	5.9	15.9
10.0	3.6	6.7	16.7
10.0	2.1	5.7	15.7
10.0	1.7	5.5	15.5
10.0	2.7	6.1	16.1
10.0	2.5	6.0	16.0
10.0	3.9	6.9	16.9
10.0	2.2	5.8	15.8
10.0	1.7	5.5	15.5
10.0	3.1	6.4	16.4
10.0	3.2	11.3	21.3
10.0	2.9	11.1	21.1
10.0	3.1	11.3	21.3
10.0	3.7	11.8	21.8
10.0	3.1	11.3	21.3

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
Lostwood W	Annual	0.6	4.5	10.0	2.9	6.2	16.2
	Winter	0.6	4.5	10.0	3.2	6.4	16.4
	Spring	0.6	4.5	10.0	2.4	5.9	15.9
	Summer	0.6	4.5	10.0	2.3	5.9	15.9
	Fall	0.6	4.5	10.0	3.5	6.6	16.6
Lye Brook W	Annual	0.9	8.5	10.0	3.0	11.2	21.2
	Winter	0.9	8.5	10.0	2.9	11.1	21.1
	Spring	0.9	8.5	10.0	2.8	11.0	21.0
	Summer	0.9	8.5	10.0	3.3	11.4	21.4
	Fall	0.9	8.5	10.0	3.1	11.3	21.3
Mammoth Cave NP	Annual	0.9	8.5	10.0	3.2	11.4	21.4
	Winter	0.9	8.5	10.0	3.3	11.5	21.5
	Spring	0.9	8.5	10.0	3.1	11.3	21.3
	Summer	0.9	8.5	10.0	3.4	11.6	21.6
	Fall	0.9	8.5	10.0	3.3	11.5	21.5
Marble Mountain W	Annual	0.6	4.5	10.0	3.1	6.3	16.3
	Winter	0.6	4.5	10.0	4.4	7.1	17.1
	Spring	0.6	4.5	10.0	2.9	6.2	16.2
	Summer	0.6	4.5	10.0	2.2	5.8	15.8
	Fall	0.6	4.5	10.0	3.8	6.8	16.8
Maroon Bells Snowmass W	Annual	0.6	4.5	10.0	1.9	5.7	15.7
	Winter	0.6	4.5	10.0	2.6	6.0	16.0
	Spring	0.6	4.5	10.0	1.7	5.5	15.5
	Summer	0.6	4.5	10.0	1.6	5.5	15.5
	Fall	0.6	4.5	10.0	2.1	5.8	15.8
Mazatzal W	Annual	0.6	4.5	10.0	1.6	5.5	15.5
	Winter	0.6	4.5	10.0	2.2	5.8	15.8
	Spring	0.6	4.5	10.0	1.3	5.3	15.3
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	1.7	5.5	15.5
Medicine Lake W	Annual	0.6	4.5	10.0	2.8	6.2	16.2
	Winter	0.6	4.5	10.0	3.2	6.4	16.4
	Spring	0.6	4.5	10.0	2.4	5.9	15.9
	Summer	0.6	4.5	10.0	2.2	5.8	15.8
	Fall	0.6	4.5	10.0	3.5	6.6	16.6

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
Mesa Verde NP	Annual	0.6	4.5	10.0	1.9	5.6	15.6
	Winter	0.6	4.5	10.0	2.6	6.1	16.1
	Spring	0.6	4.5	10.0	1.5	5.4	15.4
	Summer	0.6	4.5	10.0	1.7	5.5	15.5
	Fall	0.6	4.5	10.0	2.1	5.8	15.8
Mingo W	Annual	0.9	8.5	10.0	3.2	11.3	21.3
	Winter	0.9	8.5	10.0	3.3	11.4	21.4
	Spring	0.9	8.5	10.0	3.0	11.2	21.2
	Summer	0.9	8.5	10.0	3.3	11.4	21.4
	Fall	0.9	8.5	10.0	3.2	11.4	21.4
Mission Mountains W	Annual	0.6	4.5	10.0	2.7	6.1	16.1
	Winter	0.6	4.5	10.0	4.0	6.9	16.9
	Spring	0.6	4.5	10.0	2.5	6.0	16.0
	Summer	0.6	4.5	10.0	2.0	5.7	15.7
	Fall	0.6	4.5	10.0	3.6	6.7	16.7
Mokelumne W	Annual	0.6	4.5	10.0	2.0	5.7	15.7
	Winter	0.6	4.5	10.0	3.3	6.5	16.5
	Spring	0.6	4.5	10.0	1.7	5.5	15.5
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	2.4	5.9	15.9
Moosehorn W	Annual	0.9	8.5	10.0	3.0	11.2	21.2
	Winter	0.9	8.5	10.0	2.9	11.2	21.2
	Spring	0.9	8.5	10.0	2.8	11.0	21.0
	Summer	0.9	8.5	10.0	3.2	11.4	21.4
	Fall	0.9	8.5	10.0	3.2	11.4	21.4
Mount Adams W	Annual	0.6	4.5	10.0	3.6	6.7	16.7
	Winter	0.6	4.5	10.0	4.7	7.3	17.3
	Spring	0.6	4.5	10.0	3.2	6.4	16.4
	Summer	0.6	4.5	10.0	2.5	6.0	16.0
	Fall	0.6	4.5	10.0	5.0	7.5	17.5
Mount Baldy W	Annual	0.6	4.5	10.0	1.7	5.5	15.5
	Winter	0.6	4.5	10.0	2.3	5.9	15.9
	Spring	0.6	4.5	10.0	1.3	5.3	15.3
	Summer	0.6	4.5	10.0	1.6	5.5	15.5
	Fall	0.6	4.5	10.0	1.8	5.6	15.6

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
Mount Hood W	Annual	0.6	4.5	10.0	3.7	6.7	16.7
	Winter	0.6	4.5	10.0	4.7	7.3	17.3
	Spring	0.6	4.5	10.0	3.4	6.5	16.5
	Summer	0.6	4.5	10.0	2.6	6.1	16.1
	Fall	0.6	4.5	10.0	5.2	7.6	17.6
Mount Jefferson W	Annual	0.6	4.5	10.0	3.7	6.7	16.7
	Winter	0.6	4.5	10.0	4.8	7.4	17.4
	Spring	0.6	4.5	10.0	3.4	6.5	16.5
	Summer	0.6	4.5	10.0	2.5	6.0	16.0
	Fall	0.6	4.5	10.0	5.2	7.6	17.6
Mount Rainier NP	Annual	0.6	4.5	10.0	3.8	6.8	16.8
	Winter	0.6	4.5	10.0	4.6	7.3	17.3
	Spring	0.6	4.5	10.0	3.4	6.5	16.5
	Summer	0.6	4.5	10.0	2.7	6.1	16.1
	Fall	0.6	4.5	10.0	5.2	7.6	17.6
Mount Washington W	Annual	0.6	4.5	10.0	3.7	6.7	16.7
	Winter	0.6	4.5	10.0	4.8	7.4	17.4
	Spring	0.6	4.5	10.0	3.4	6.5	16.5
	Summer	0.6	4.5	10.0	2.5	6.0	16.0
	Fall	0.6	4.5	10.0	5.1	7.6	17.6
Mount Zirkel W	Annual	0.6	4.5	10.0	2.0	5.7	15.7
	Winter	0.6	4.5	10.0	2.5	6.0	16.0
	Spring	0.6	4.5	10.0	1.9	5.6	15.6
	Summer	0.6	4.5	10.0	1.7	5.5	15.5
	Fall	0.6	4.5	10.0	2.2	5.8	15.8
Mountain Lakes W	Annual	0.6	4.5	10.0	2.8	6.2	16.2
	Winter	0.6	4.5	10.0	4.4	7.2	17.2
	Spring	0.6	4.5	10.0	2.6	6.1	16.1
	Summer	0.6	4.5	10.0	1.9	5.7	15.7
	Fall	0.6	4.5	10.0	3.8	6.8	16.8
North Absoraka W	Annual	0.6	4.5	10.0	2.2	5.8	15.8
	Winter	0.6	4.5	10.0	2.9	6.2	16.2
	Spring	0.6	4.5	10.0	2.1	5.8	15.8
	Summer	0.6	4.5	10.0	1.7	5.5	15.5
	Fall	0.6	4.5	10.0	2.5	6.0	16.0

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
North Cascades NP	Annual	0.6	4.5	10.0	3.8	6.8	16.8
	Winter	0.6	4.5	10.0	4.2	7.0	17.0
	Spring	0.6	4.5	10.0	3.4	6.5	16.5
	Summer	0.6	4.5	10.0	2.8	6.2	16.2
	Fall	0.6	4.5	10.0	5.1	7.6	17.6
Okefenokee W	Annual	0.9	8.5	10.0	3.5	11.7	21.7
	Winter	0.9	8.5	10.0	3.2	11.3	21.3
	Spring	0.9	8.5	10.0	3.4	11.5	21.5
	Summer	0.9	8.5	10.0	3.9	12.0	22.0
	Fall	0.9	8.5	10.0	3.6	11.7	21.7
Olympic NP	Annual	0.6	4.5	10.0	4.5	7.2	17.2
	Winter	0.6	4.5	10.0	4.4	7.2	17.2
	Spring	0.6	4.5	10.0	4.1	7.0	17.0
	Summer	0.6	4.5	10.0	3.4	6.5	16.5
	Fall	0.6	4.5	10.0	5.8	8.0	18.0
Otter Creek W	Annual	0.9	8.5	10.0	3.2	11.3	21.3
	Winter	0.9	8.5	10.0	3.0	11.2	21.2
	Spring	0.9	8.5	10.0	3.0	11.2	21.2
	Summer	0.9	8.5	10.0	3.5	11.6	21.6
	Fall	0.9	8.5	10.0	3.2	11.4	21.4
Pasayten W	Annual	0.6	4.5	10.0	3.7	6.7	16.7
	Winter	0.6	4.5	10.0	3.8	6.8	16.8
	Spring	0.6	4.5	10.0	3.3	6.5	16.5
	Summer	0.6	4.5	10.0	2.7	6.1	16.1
	Fall	0.6	4.5	10.0	5.0	7.5	17.5
Pecos W	Annual	0.6	4.5	10.0	1.8	5.6	15.6
	Winter	0.6	4.5	10.0	2.3	5.9	15.9
	Spring	0.6	4.5	10.0	1.5	5.4	15.4
	Summer	0.6	4.5	10.0	1.8	5.6	15.6
	Fall	0.6	4.5	10.0	2.0	5.7	15.7
Petrified Forest NP	Annual	0.6	4.5	10.0	1.7	5.5	15.5
	Winter	0.6	4.5	10.0	2.5	6.0	16.0
	Spring	0.6	4.5	10.0	1.3	5.3	15.3
	Summer	0.6	4.5	10.0	1.6	5.5	15.5
	Fall	0.6	4.5	10.0	1.9	5.6	15.6

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
Pine Mountain W	Annual	0.6	4.5	10.0	1.6	5.5	15.5
	Winter	0.6	4.5	10.0	2.3	5.9	15.9
	Spring	0.6	4.5	10.0	1.3	5.3	15.3
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	1.7	5.5	15.5
Pinnacles NM (W)	Annual	0.6	4.5	10.0	2.4	5.9	15.9
	Winter	0.6	4.5	10.0	3.4	6.5	16.5
	Spring	0.6	4.5	10.0	2.1	5.8	15.8
	Summer	0.6	4.5	10.0	2.0	5.7	15.7
	Fall	0.6	4.5	10.0	2.7	6.1	16.1
Point Reyes NS (W)	Annual	0.6	4.5	10.0	3.0	6.3	16.3
	Winter	0.6	4.5	10.0	3.9	6.9	16.9
	Spring	0.6	4.5	10.0	2.7	6.1	16.1
	Summer	0.6	4.5	10.0	2.5	6.0	16.0
	Fall	0.6	4.5	10.0	3.1	6.4	16.4
Presidential Range Dry River W	Annual	0.9	8.5	10.0	3.0	11.2	21.2
	Winter	0.9	8.5	10.0	2.8	11.0	21.0
	Spring	0.9	8.5	10.0	2.8	11.0	21.0
	Summer	0.9	8.5	10.0	3.3	11.5	21.5
	Fall	0.9	8.5	10.0	3.1	11.3	21.3
Rawah W	Annual	0.6	4.5	10.0	2.1	5.7	15.7
	Winter	0.6	4.5	10.0	2.5	6.0	16.0
	Spring	0.6	4.5	10.0	2.0	5.7	15.7
	Summer	0.6	4.5	10.0	1.8	5.6	15.6
	Fall	0.6	4.5	10.0	2.2	5.8	15.8
Red Rock Lakes W	Annual	0.6	4.5	10.0	2.2	5.8	15.8
	Winter	0.6	4.5	10.0	3.2	6.4	16.4
	Spring	0.6	4.5	10.0	2.1	5.8	15.8
	Summer	0.6	4.5	10.0	1.7	5.5	15.5
	Fall	0.6	4.5	10.0	2.7	6.1	16.1
Redwood NP	Annual	0.6	4.5	10.0	4.2	7.0	17.0
	Winter	0.6	4.5	10.0	4.6	7.3	17.3
	Spring	0.6	4.5	10.0	4.3	7.1	17.1
	Summer	0.6	4.5	10.0	3.2	6.4	16.4
	Fall	0.6	4.5	10.0	4.6	7.3	17.3

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
Rocky Mountain NP	Annual	0.6	4.5	10.0	2.1	5.7	15.7
	Winter	0.6	4.5	10.0	2.5	6.0	16.0
	Spring	0.6	4.5	10.0	2.0	5.7	15.7
	Summer	0.6	4.5	10.0	1.8	5.6	15.6
	Fall	0.6	4.5	10.0	2.2	5.8	15.8
Saguaro NP	Annual	0.6	4.5	10.0	1.6	5.4	15.4
	Winter	0.6	4.5	10.0	2.1	5.7	15.7
	Spring	0.6	4.5	10.0	1.2	5.2	15.2
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	1.6	5.5	15.5
Salt Creek W	Annual	0.6	4.5	10.0	1.8	5.6	15.6
	Winter	0.6	4.5	10.0	2.1	5.8	15.8
	Spring	0.6	4.5	10.0	1.5	5.4	15.4
	Summer	0.6	4.5	10.0	1.9	5.6	15.6
	Fall	0.6	4.5	10.0	1.8	5.6	15.6
San Gabriel W	Annual	0.6	4.5	10.0	2.4	5.9	15.9
	Winter	0.6	4.5	10.0	2.4	5.9	15.9
	Spring	0.6	4.5	10.0	2.4	6.0	16.0
	Summer	0.6	4.5	10.0	2.4	5.9	15.9
	Fall	0.6	4.5	10.0	2.2	5.8	15.8
San Gorgonio W	Annual	0.6	4.5	10.0	2.2	5.8	15.8
	Winter	0.6	4.5	10.0	2.3	5.9	15.9
	Spring	0.6	4.5	10.0	2.2	5.8	15.8
	Summer	0.6	4.5	10.0	2.1	5.8	15.8
	Fall	0.6	4.5	10.0	2.1	5.8	15.8
San Jacinto W	Annual	0.6	4.5	10.0	2.3	5.9	15.9
	Winter	0.6	4.5	10.0	2.3	5.9	15.9
	Spring	0.6	4.5	10.0	2.3	5.9	15.9
	Summer	0.6	4.5	10.0	2.2	5.8	15.8
	Fall	0.6	4.5	10.0	2.1	5.8	15.8
San Pedro Parks W	Annual	0.6	4.5	10.0	1.8	5.6	15.6
	Winter	0.6	4.5	10.0	2.4	6.0	16.0
	Spring	0.6	4.5	10.0	1.5	5.4	15.4
	Summer	0.6	4.5	10.0	1.7	5.5	15.5
	Fall	0.6	4.5	10.0	2.0	5.7	15.7

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
San Rafael W	Annual	0.6	4.5	10.0	2.6	6.1	16.1
	Winter	0.6	4.5	10.0	2.7	6.1	16.1
	Spring	0.6	4.5	10.0	2.6	6.0	16.0
	Summer	0.6	4.5	10.0	2.5	6.0	16.0
	Fall	0.6	4.5	10.0	2.5	6.0	16.0
Sawtooth W	Annual	0.6	4.5	10.0	2.2	5.8	15.8
	Winter	0.6	4.5	10.0	4.0	6.9	16.9
	Spring	0.6	4.5	10.0	2.0	5.7	15.7
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	2.9	6.2	16.2
Scapegoat W	Annual	0.6	4.5	10.0	2.5	6.0	16.0
	Winter	0.6	4.5	10.0	3.5	6.6	16.6
	Spring	0.6	4.5	10.0	2.4	5.9	15.9
	Summer	0.6	4.5	10.0	1.9	5.6	15.6
	Fall	0.6	4.5	10.0	3.1	6.3	16.3
Selway – Bitterroot W	Annual	0.6	4.5	10.0	2.6	6.0	16.0
	Winter	0.6	4.5	10.0	4.0	6.9	16.9
	Spring	0.6	4.5	10.0	2.3	5.9	15.9
	Summer	0.6	4.5	10.0	1.8	5.6	15.6
	Fall	0.6	4.5	10.0	3.4	6.5	16.5
Seney W	Annual	0.9	8.5	10.0	3.6	11.8	21.8
	Winter	0.9	8.5	10.0	3.7	11.8	21.8
	Spring	0.9	8.5	10.0	2.9	11.1	21.1
	Summer	0.9	8.5	10.0	3.6	11.7	21.7
	Fall	0.9	8.5	10.0	4.2	12.3	22.3
Sequoia NP	Annual	0.6	4.5	10.0	2.0	5.7	15.7
	Winter	0.6	4.5	10.0	2.7	6.1	16.1
	Spring	0.6	4.5	10.0	1.8	5.6	15.6
	Summer	0.6	4.5	10.0	1.6	5.5	15.5
	Fall	0.6	4.5	10.0	2.1	5.8	15.8
Shenandoah NP	Annual	0.9	8.5	10.0	3.0	11.2	21.2
	Winter	0.9	8.5	10.0	2.9	11.1	21.1
	Spring	0.9	8.5	10.0	2.9	11.1	21.1
	Summer	0.9	8.5	10.0	3.4	11.6	21.6
	Fall	0.9	8.5	10.0	3.1	11.3	21.3

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
Shining Rock W	Annual	0.9	8.5	10.0	3.2	11.4	21.4
	Winter	0.9	8.5	10.0	2.9	11.1	21.1
	Spring	0.9	8.5	10.0	3.1	11.3	21.3
	Summer	0.9	8.5	10.0	3.7	11.9	21.9
	Fall	0.9	8.5	10.0	3.2	11.3	21.3
Sierra Ancha W	Annual	0.6	4.5	10.0	1.6	5.5	15.5
	Winter	0.6	4.5	10.0	2.2	5.8	15.8
	Spring	0.6	4.5	10.0	1.3	5.3	15.3
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	1.7	5.5	15.5
Sipsey W	Annual	0.9	8.5	10.0	3.3	11.5	21.5
	Winter	0.9	8.5	10.0	3.2	11.4	21.4
	Spring	0.9	8.5	10.0	3.3	11.4	21.4
	Summer	0.9	8.5	10.0	3.5	11.7	21.7
	Fall	0.9	8.5	10.0	3.3	11.5	21.5
South Warner W	Annual	0.6	4.5	10.0	2.1	5.8	15.8
	Winter	0.6	4.5	10.0	3.6	6.7	16.7
	Spring	0.6	4.5	10.0	1.9	5.6	15.6
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	2.6	6.1	16.1
St. Marks W	Annual	0.9	8.5	10.0	3.6	11.8	21.8
	Winter	0.9	8.5	10.0	3.2	11.4	21.4
	Spring	0.9	8.5	10.0	3.5	11.7	21.7
	Summer	0.9	8.5	10.0	4.0	12.1	22.1
	Fall	0.9	8.5	10.0	3.6	11.8	21.8
Strawberry Mountain W	Annual	0.6	4.5	10.0	2.6	6.1	16.1
	Winter	0.6	4.5	10.0	4.4	7.1	17.1
	Spring	0.6	4.5	10.0	2.4	5.9	15.9
	Summer	0.6	4.5	10.0	1.8	5.6	15.6
	Fall	0.6	4.5	10.0	3.7	6.7	16.7
Superstition W	Annual	0.6	4.5	10.0	1.6	5.4	15.4
	Winter	0.6	4.5	10.0	2.1	5.8	15.8
	Spring	0.6	4.5	10.0	1.2	5.2	15.2
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	1.6	5.5	15.5

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
Swanquarter W	Annual	0.9	8.5	10.0	3.3	11.5	21.5
	Winter	0.9	8.5	10.0	2.9	11.1	21.1
	Spring	0.9	8.5	10.0	3.3	11.4	21.4
	Summer	0.9	8.5	10.0	3.8	11.9	21.9
	Fall	0.9	8.5	10.0	3.2	11.4	21.4
Sycamore Canyon W	Annual	0.6	4.5	10.0	1.7	5.5	15.5
	Winter	0.6	4.5	10.0	2.3	5.9	15.9
	Spring	0.6	4.5	10.0	1.4	5.3	15.3
	Summer	0.6	4.5	10.0	1.6	5.5	15.5
	Fall	0.6	4.5	10.0	1.8	5.6	15.6
Teton W	Annual	0.6	4.5	10.0	2.1	5.8	15.8
	Winter	0.6	4.5	10.0	2.9	6.2	16.2
	Spring	0.6	4.5	10.0	2.0	5.7	15.7
	Summer	0.6	4.5	10.0	1.6	5.5	15.5
	Fall	0.6	4.5	10.0	2.5	6.0	16.0
Theodore Roosevelt NP	Annual	0.6	4.5	10.0	2.7	6.1	16.1
	Winter	0.6	4.5	10.0	3.7	6.7	16.7
	Spring	0.6	4.5	10.0	2.5	6.0	16.0
	Summer	0.6	4.5	10.0	2.1	5.8	15.8
	Fall	0.6	4.5	10.0	3.2	6.4	16.4
Thousand Lakes W	Annual	0.6	4.5	10.0	2.3	5.9	15.9
	Winter	0.6	4.5	10.0	3.7	6.7	16.7
	Spring	0.6	4.5	10.0	2.1	5.8	15.8
	Summer	0.6	4.5	10.0	1.7	5.5	15.5
	Fall	0.6	4.5	10.0	2.8	6.2	16.2
Three Sisters W	Annual	0.6	4.5	10.0	3.7	6.7	16.7
	Winter	0.6	4.5	10.0	4.9	7.4	17.4
	Spring	0.6	4.5	10.0	3.4	6.6	16.6
	Summer	0.6	4.5	10.0	2.5	6.0	16.0
	Fall	0.6	4.5	10.0	5.1	7.6	17.6
U.L. Bend W	Annual	0.6	4.5	10.0	2.4	5.9	15.9
	Winter	0.6	4.5	10.0	3.3	6.5	16.5
	Spring	0.6	4.5	10.0	2.3	5.9	15.9
	Summer	0.6	4.5	10.0	1.8	5.6	15.6
	Fall	0.6	4.5	10.0	2.8	6.2	16.2

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
Upper Buffalo W	Annual	0.9	8.5	10.0	3.1	11.3	21.3
	Winter	0.9	8.5	10.0	3.2	11.4	21.4
	Spring	0.9	8.5	10.0	3.1	11.3	21.3
	Summer	0.9	8.5	10.0	3.2	11.4	21.4
	Fall	0.9	8.5	10.0	3.2	11.3	21.3
Ventana W	Annual	0.6	4.5	10.0	2.5	6.0	16.0
	Winter	0.6	4.5	10.0	3.4	6.5	16.5
	Spring	0.6	4.5	10.0	2.2	5.8	15.8
	Summer	0.6	4.5	10.0	2.1	5.8	15.8
	Fall	0.6	4.5	10.0	2.7	6.1	16.1
Voyageurs NP	Annual	0.9	8.5	10.0	3.4	11.5	21.5
	Winter	0.9	8.5	10.0	3.7	11.8	21.8
	Spring	0.9	8.5	10.0	2.6	10.8	20.8
	Summer	0.9	8.5	10.0	3.4	11.6	21.6
	Fall	0.9	8.5	10.0	4.1	12.2	22.2
Washakie W	Annual	0.6	4.5	10.0	2.1	5.8	15.8
	Winter	0.6	4.5	10.0	2.8	6.2	16.2
	Spring	0.6	4.5	10.0	2.0	5.7	15.7
	Summer	0.6	4.5	10.0	1.6	5.5	15.5
	Fall	0.6	4.5	10.0	2.5	6.0	16.0
Weminuche W	Annual	0.6	4.5	10.0	1.9	5.6	15.6
	Winter	0.6	4.5	10.0	2.5	6.0	16.0
	Spring	0.6	4.5	10.0	1.6	5.4	15.4
	Summer	0.6	4.5	10.0	1.7	5.5	15.5
	Fall	0.6	4.5	10.0	2.1	5.8	15.8
West Elk W	Annual	0.6	4.5	10.0	1.9	5.6	15.6
	Winter	0.6	4.5	10.0	2.6	6.1	16.1
	Spring	0.6	4.5	10.0	1.7	5.5	15.5
	Summer	0.6	4.5	10.0	1.6	5.5	15.5
	Fall	0.6	4.5	10.0	2.1	5.8	15.8
Wheeler Peak W	Annual	0.6	4.5	10.0	1.9	5.6	15.6
	Winter	0.6	4.5	10.0	2.4	5.9	15.9
	Spring	0.6	4.5	10.0	1.6	5.5	15.5
	Summer	0.6	4.5	10.0	1.8	5.6	15.6
	Fall	0.6	4.5	10.0	2.1	5.8	15.8

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
White Mountain W	Annual	0.6	4.5	10.0	1.8	5.6	15.6
	Winter	0.6	4.5	10.0	2.2	5.8	15.8
	Spring	0.6	4.5	10.0	1.4	5.4	15.4
	Summer	0.6	4.5	10.0	1.8	5.6	15.6
	Fall	0.6	4.5	10.0	1.8	5.6	15.6
Wichita Mountain W	Annual	0.6	4.5	10.0	2.6	6.1	16.1
	Winter	0.6	4.5	10.0	2.7	6.1	16.1
	Spring	0.6	4.5	10.0	2.8	6.2	16.2
	Summer	0.6	4.5	10.0	2.5	6.0	16.0
	Fall	0.6	4.5	10.0	2.6	6.1	16.1
Wind Cave NP	Annual	0.6	4.5	10.0	2.5	6.0	16.0
	Winter	0.6	4.5	10.0	2.9	6.2	16.2
	Spring	0.6	4.5	10.0	2.5	6.0	16.0
	Summer	0.6	4.5	10.0	2.1	5.7	15.7
	Fall	0.6	4.5	10.0	2.6	6.1	16.1
Wolf Island W	Annual	0.9	8.5	10.0	3.5	11.6	21.6
	Winter	0.9	8.5	10.0	3.1	11.3	21.3
	Spring	0.9	8.5	10.0	3.3	11.5	21.5
	Summer	0.9	8.5	10.0	3.9	12.0	22.0
	Fall	0.9	8.5	10.0	3.6	11.7	21.7
Yellowstone NP	Annual	0.6	4.5	10.0	2.2	5.8	15.8
	Winter	0.6	4.5	10.0	3.0	6.3	16.3
	Spring	0.6	4.5	10.0	2.1	5.8	15.8
	Summer	0.6	4.5	10.0	1.7	5.5	15.5
	Fall	0.6	4.5	10.0	2.5	6.0	16.0
Yolla Bolly – Middle Eel W	Annual	0.6	4.5	10.0	2.6	6.1	16.1
	Winter	0.6	4.5	10.0	3.8	6.8	16.8
	Spring	0.6	4.5	10.0	2.4	5.9	15.9
	Summer	0.6	4.5	10.0	2.0	5.7	15.7
	Fall	0.6	4.5	10.0	3.0	6.3	16.3
Yosemite NP	Annual	0.6	4.5	10.0	2.0	5.7	15.7
	Winter	0.6	4.5	10.0	3.1	6.4	16.4
	Spring	0.6	4.5	10.0	1.7	5.5	15.5
	Summer	0.6	4.5	10.0	1.5	5.4	15.4
	Fall	0.6	4.5	10.0	2.3	5.9	15.9

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle bext w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1})
		Hygro	Non Hygro	Rayleigh			
Zion NP	Annual	0.6	4.5	10.0	1.7	5.5	15.5
	Winter	0.6	4.5	10.0	2.7	6.1	16.1
	Spring	0.6	4.5	10.0	1.4	5.3	15.3
	Summer	0.6	4.5	10.0	1.3	5.3	15.3
	Fall	0.6	4.5	10.0	1.9	5.6	15.6
Seasonal RH data not available; contact FLM							
Bering Sea W		0.6	4.5	10.0	Contact the FLM		
Denali NP		0.6	4.5	10.0	Contact the FLM		
Haleakala NP		0.6	4.5	10.0	Contact the FLM		
Hawaii Volcanoes NP		0.6	4.5	10.0			
Roosevelt Campobello IP		0.9	8.5	10.0	Contact the FLM		
Simeonof W		0.6					

10.0 Contact 438 Tj Contact 423 Tj 10.0
Hawaii Volcano Contact 4540 0 0.6 0.6 4.5 10.0 Contact 4680

Table 2.B-2 Estimated Annual Average Natural Background Levels of Aerosols		
Particulate Aerosol Component	Annual Average Concentration	
	East ($\mu g/m^3$)	West ($\mu g/m^3$)
Sulfates (as ammonium sulfate)	0.2	0.1
Ammonium Nitrate	0.1	0.1
Organics	1.5	0.5
Elemental Carbon	0.02	0.02
Soil Dust	0.5	0.5
Coarse	3.0	3.0

Taken from NAPAP 1990. West refers to those States beyond the first tier of States west of the Mississippi River.

Appendix 2.C
Example Problem

Example applications for coherent plumes that are viewed against a scenic background are provided in the *Workbook for Plume Visual Impact Screening and Analysis* (USEPS, 1992a), so no specific example needs to be supplied here. The analysis of a plume or aggregation of plumes that affects the appearance of a scene does involve some new concepts, so an example application is being provided. The example is given for two cases, first for a general model application where a visibility post processor is not available, and a second case for the CALMET/CALPUFF/CALPOST modeling system.

General Model Application

For the purposes of general application, let us assume that a dispersion model has been run and yielded daily (24-hour) concentrations of $SO_4^{=}$ (sulfate) and soot (elemental carbon). From these concentrations the analyst can calculate a change in extinction from some specified reference level using the procedures given in Appendix 2.A. The first step is to calculate the visibility reference level for the Class I area of interest from the information provided in Appendix 2.B. Then, one calculates the new source's contribution to extinction and the expected change in extinction from the reference level. This example will only address one 24-hour time period. The calculation would, of course, have to be repeated for the other 24-hour time periods as well as, accounting for the seasonal differences.

<u>Calculation of the Reference Level</u>

The determination of the reference level for a single 24-hour period in January visibility condition can be made by examining the example table below (for an actual case, the applicant would turn to Appendix 2.B). While the reference extinction for Acadia NP is provided in the table (21.1Mm^{-1}), it is useful to go through the calculation to see how to apply the different numbers in the table.

Site	Season	Components of Dry Extinction (Mm^{-1})			f(RH)	Particle b_{ext} w/f(RH) (Mm^{-1})	Reference Level (Mm^{-1}) b_{ref}
		Hygro	Non Hygro	Rayleigh			
Acadia NP	Annual	0.9	8.5	10.0	3.0	11.2	21.2
	Winter	0.9	8.5	10.0	2.9	11.1	21.1
	Spring	0.9	8.5	10.0	2.8	11.0	21.0
	Summer	0.9	8.5	10.0	3.2	11.4	21.4
	Fall	0.9	8.5	10.0	3.1	11.3	21.3

The reference extinction (b_{ref}), expressed in the form of Equation 6 (Appendix 2.A) would be b_{ref} = 0.9 f(RH) + 8.5 + 10.0 (see Equation 6, Appendix 2.A). The f(RH) term in the example table (for January) is 2.9, yielding an extinction coefficient of 21.1 Mm^{-1}. If one were using site specific, hourly relative humidity data, one would have to calculate the average f(RH) for that 24-hour period. To do this, one needs to look up the f(RH) value corresponding to each hour's relative humidity in Table 2.A-1 (Appendix 2.A) and take the average of those f(RH) values. One <u>can not</u> take the average of the relative humidity and look up the f(RH) in the table; that would yield an incorrect result. (Similarly, the f(RH) values shown in the example table and in Appendix 2.B are generated using annual and seasonal average relative humidity estimates and the empirical curve for f(RH) given in IMPROVE 2000. Annual and seasonal averages of f(RH) do not directly correspond to the relative humidity values in Table 2.A-1.)

Calculation of Single-Source Contribution

In a typical modeling analysis, IWAQM recommends, and the FLMs endorse, the use of five years of meteorological data. This will produce a corresponding number of block 24-hour averaging periods, which will each need to be compared with the reference condition.

Again for purposes of illustration we will only show the calculation of extinction for one modeled 24-hour period in January. This calculation would then have to be repeated for all other 24-hour periods. For this example we will assume that the sources in the analysis contributed 0.3 $\mu g/m^3$ of sulfate ($SO_4^=$) and 0.10 $\mu g/m^3$ of soot (elemental carbon), 24-hour average. The first step is to convert the mass of $SO_4^=$ to ammonium sulfate ($(NH_4)_2SO_4$), which is accomplished by multiplying by the ratio of the molecular weights of $(NH_4)_2SO_4$ to $SO_4^=$, which is 1.375. This yields a concentration of $(NH_4)_2SO_4$ of 0.4 $\mu g/m^3$. This is then multiplied by the "dry" scattering efficiency of $(NH_4)_2SO_4$ (which is 3, from Appendix 2.A, Equation 3), yielding an extinction coefficient for the sulfate of 1.2 Mm^{-1}; the relative humidity adjustment has not yet been applied.

In this example our modeling does not require any conversion of the mass of soot, so we will just multiply the soot concentration (0.10 $\mu g/m^3$) by the extinction efficiency of elemental carbon (which is 10, from Appendix 2.A, Equation 4). This yields an extinction coefficient of 1.0 Mm^{-1}. Therefore, following the form of Equations 3 and 5 (Appendix 2.A), the source contribution would be:

$$b_{source} = 1.2\ f(RH) + 1.0$$

A representative relative humidity adjustment term, f(RH), must be applied. It is important that the same adjustment be made to both the source contribution to extinction and the reference level. For a screening level analysis, the relative humidity adjustment factors listed in Appendix 2.B can be applied to the source contributions. For example, if we are analyzing for Acadia NP, the average winter f(RH) is 2.9. With the winter quarterly average relative humidity adjustment factor (f(RH)) of 2.9, b_{source} would be 4.5 Mm^{-1}.

Calculation of the Change in Extinction

The resulting percent change in extinction is found from:

$$\Delta b_{ext} = (b_{source}/b_{ref}) \times 100\%$$

For the example here, b_{source} = 4.5 Mm^{-1} and b_{ref} = 22.1 Mm^{-1}, yielding Δb_{ext} = 20%. This calculation must be repeated for each 24-hour averaging period. To portray the frequency, magnitude, and geographic extent of expected impairment, this calculation will have to be repeated for all days and many receptors in the modeling domain. FLAG expects a robust selection of model receptor locations in the Class I area be included in the analyses, *i.e.*, one receptor representing the entire area, or just the nearest boundary, will not be sufficient.

Example using the CALMET/CALPUFF/CALPOST modeling system

For the refined analysis, it is necessary to calculate the change in extinction for the relative humidity conditions on a specific day. To accomplish this, the representative, hourly RH values for this day need to be obtained. For each hour, the corresponding f(RH) must be obtained from Table 2.A-1. These f(RH) values are then averaged together. These calculations would have to be repeated for each 24-hour average concentration, at each receptor, in the analysis, using the corresponding average f(RH), and be applied to both the aerosol data in Table 2.B-1 (to determine the reference level) and the source contribution to extinction.

In the case of a CALPUFF application, the post-processor, CALPOST, has been set up to directly calculate the combined visibility effects from different visibility impairing pollutants. Refer to Figure 2.C-1 for an example of the visibility parameters to set in the CALPOST input file. Most of the parameters set in CALPOST are application specific. The pollutants in the example are sulfate and soot (elemental carbon). CALPOST allows for the specification of sulfate (SO4), but not elemental carbon in the source portion of the visibility calculation. (This should be rectified in the next update of the modeling system.) Therefore elemental carbon will be modeled as PM fine (PMF). In CALPOST the variables LVSO4 and LVPMF are set to true. Since elemental carbon is being modeled as PMF, the extinction efficiency for PMF must be set to that for elemental carbon (EEPMF = 10.0). FLAG is recommending that the default f(RH) values in Appendix 2.B be used for screening analyses for each Class I area. Therefore, MVISBK would be set to 6. When MVISBK is set to 6, RHFAC would be set to the f(RH) value in Appendix 2.B or in this example, it would be set to 2.9 for the winter months (Dec, Jan, Feb). CALPOST does not explicitly allow for the input of the hygroscopic and non-hygroscopic components to extinction at this time; it only allows for the input of the concentrations of particulate species. To properly input the components to extinction, the hygroscopic component of extinction is divided by 3 (the extinction efficiency of sulfate and nitrate) and is input to the variable BKSO4. In this example the hygroscopic component of extinction is 0.9; after dividing by 3 we get a value of 0.3, which is input to CALPOST (BKSO4 = 0.3). For the non-hygroscopic component, enter its value into the variable BKSOIL (BKSOIL = 8.5) (also make sure that EESOIL is set to 1.0). All other background concentrations must be set to zero (0.0). Finally, a value for the extinction due to Rayleigh scattering must be entered (BEXTRAY = 10.0).

If MVISBK=2 (hour-by-hour calculation of f(RH)) in the above example, the hour-by-hour relative humidity values from CALMET would be used to calculate the 24-hour average extinction, rather than the long-term average f(RH) values supplied in Appendix 2.B. The only modification to the input would be that the value of RHMAX (set to 98.0 in the example) would be used to cap the maximum f(RH) used in the averages, and the value of RHFAC would not be used. A “vis.dat” file (not shown in Figure 2.C-1) would also be specified. It must be generated when CALPUFF is run.

Figure 2.C-1. Segment of CALPOST input file corresponding to example problem.

```
---------------------------------------------------------------------------

INPUT GROUP: 2 -- Visibility Parameters (ASPEC = VISIB)
--------------
```

Set RHMAX = 98.0 (for MVISBK=2)

```
    Maximum relative humidity (%) used in particle growth curve
                           (RHMAX) -- Default: 98   ! RHMAX  = 98.0 !
```

Set the flags for the pollutants modeled. In the example problem SO4 and EC (Modeled as PMF)

```
    Modeled species to be included in computing the light extinction
     Include SULFATE?          (LVSO4) -- Default: T   ! LVSO4  = T  !
     Include NITRATE?          (LVNO3) -- Default: T   ! LVNO3  = F  !
     Include ORGANIC CARBON?   (LVOC)  -- Default: T   ! LVOC   = F  !
     Include COARSE PARTICLES? (LVPMC) -- Default: T   ! LVPMC  = F  !
     Include FINE PARTICLES?   (LVPMF) -- Default: T   ! LVPMF  = T  !

    And, when ranking for TOP-N, TOP-50, and Exceedance tables,
     Include BACKGROUND?       (LVBK)  -- Default: T   ! LVBK   = T  !

    Species name used for particulates in MODEL.DAT file
                   COARSE    (SPECPMC) -- Default: PMC ! SPECPMC = PMC !
                   FINE      (SPECPMF) -- Default: PMF ! SPECPMF = PMF !

Extinction Efficiency (1/Mm per ug/m**3)
----------------------------------------
    MODELED particulate species:
              PM  COARSE      (EEPMC) -- Default: 0.6 ! EEPMC  = 0.6 !
              PM  FINE        (EEPMF) -- Default: 1.0 ! EEPMF  = 10.0 !
    BACKGROUND particulate species:
              PM  COARSE    (EEPMCBK) -- Default: 0.6 ! EEPMCBK = 0.6 !
    Other species:
             AMMONIUM SULFATE (EESO4) -- Default: 3.0 ! EESO4  = 3.0 !
             AMMONIUM NITRATE (EENO3) -- Default: 3.0 ! EENO3  = 3.0 !
             ORGANIC CARBON   (EEOC)  -- Default: 4.0 ! EEOC   = 4.0 !
             SOIL             (EESOIL)-- Default: 1.0 ! EESOIL = 1.0 !
             ELEMENTAL CARBON (EEEC)  -- Default: 10. ! EEEC   = 10.0 !
```

Note: in the example problem, the source's elemental carbon (EC) is modeled as PMFINE (PMF). To calculate the extinction for EC as PMF the variable EEPMF needs to be reset to 10.0

Figure 2.C-1 (Cont). Segment of CALPOST input file corresponding to example problem.

For Screening Analysis MVISBK = 6
~~Set RHFAC below~~

For Refined Analysis use MVISBK = 2
Specify a "vis.dat" file in CALPUFF

```
Background Extinction Computation
---------------------------------

    Method used for background light extinction
                          (MVISBK) -- Default: 6   ! MVISBK =  2  !

         1 =  Supply single light extinction and hygroscopic fraction
IWAQM (1993) RH adjustment applied to hygroscopic
background
                and modeled sulfate and nitrate
         2 =  Compute extinction from speciated PM measurements (A)
              - Hourly RH adjustment applied to observed and modeled
                  sulfateand nitrate
              - RH factor is capped at RHMAX
         3 =  Compute extinction from speciated PM measurements (B)
              - Hourly RH adjustment applied to observed and modeled
                  sulfate and nitrate
              - Receptor-hour excluded if RH>RHMAX
              - Receptor-day excluded if fewer than 6 valid receptor-hours
         4 =  Read hourly transmissometer background extinction
                  measurements
              - Hourly RH adjustment applied to modeled sulfate and
                  nitrate
              - Hour excluded if measurement invalid (missing,
                  interference, or large RH)
              - Receptor-hour excluded if RH>RHMAX
              - Receptor-day excluded if fewer than 6 valid receptor-hours
         5 =  Read hourly nephelometer background extinction measurements
              - Rayleigh extinction value (BEXTRAY) added to measurement
              - Hourly RH adjustment applied to modeled sulfate and
                  nitrate
              - Hour excluded if measurement invalid (missing,
                  interference, or large RH)
              - Receptor-hour excluded if RH>RHMAX
              - Receptor-day excluded if fewer than 6 valid receptor-hours
         6 =  Compute extinction from speciated PM measurements
              - FLAG RH adjustment factor applied to observed and
                modeled sulfate and nitrate
```

Figure 2.C-1 (Cont). Segment of CALPOST input file corresponding to example problem.

```
    Additional inputs used for MVISBK = 6:
    --------------------------------------
     Extinction coefficients for hygroscopic species (modeled and
     background) are computed using a monthly RH adjustment factor
     in place of an hourly RH factor (VISB.DAT file is NOT needed).
     Enter the 12 monthly factors here (RHFAC).  Month 1 is January.

     (RHFAC)  -- No default     ! RHFAC = 2.9, 2.9, 2.8, 2.8,
                                          2.8, 3.2, 3.2, 3.2,
                                          3.1, 3.1, 3.1, 2.9 !
```

For screening analysis set monthly f(RH) values from Appendix 2.B

```
    Additional inputs used for MVISBK = 2,3,6:
    ----------------------------------------
     Background extinction coefficients are computed from monthly
     CONCENTRATIONS of ammonium sulfate (BKSO4), ammonium nitrate (BKNO3),
     coarse particulates (BKPMC), organic carbon (BKOC), soil (BKSOIL),
and
     elemental carbon (BKEC).  Month 1 is January.
     (ug/m**3)

     (BKSO4)  -- No default     ! BKSO4 = 0.3, 0.3, 0.3, 0.3,
                                          0.3, 0.3, 0.3, 0.3,
                                          0.3, 0.3, 0.3, 0.3 !
     (BKNO3)  -- No default     ! BKNO3 = 0.0, 0.0, 0.0, 0.0,
                                          0.0, 0.0, 0.0, 0.0,
                                          0.0, 0.0, 0.0, 0.0 !
     (BKPMC)  -- No default     ! BKPMC = 0.0, 0.0, 0.0, 0.0,
                                          0.0, 0.0, 0.0, 0.0,
                                          0.0, 0.0, 0.0, 0.0 !
     (BKOC)   -- No default     ! BKOC  = 0.0, 0.0, 0.0, 0.0,
                                          0.0, 0.0, 0.0, 0.0,
                                          0.0, 0.0, 0.0, 0.0 !
     (BKSOIL) -- No default     ! BKSOIL= 8.5, 8.5, 8.5, 8.5,
                                          8.5, 8.5, 8.5, 8.5,
                                          8.5, 8.5, 8.5, 8.5 !
     (BKEC)   -- No default     ! BKEC  = 0.0, 0.0, 0.0, 0.0,
                                          0.0, 0.0, 0.0, 0.0,
                                          0.0, 0.0, 0.0, 0.0 !

    Additional inputs used for MVISBK = 2,3,5,6:
    ------------------------------------------
     Extinction due to Rayleigh scattering is added (1/Mm)
                         (BEXTRAY) -- Default: 10.0 ! BEXTRAY = 10.0 !
```

Background extinction values (Appendix 2.B) set to:
BKSO4 = Hygroscopic / 3
BKSOIL = Non-Hygroscopic
BKNO3, BKPMC, BKOC, BKEC = 0.0

3. OZONE

a. Introduction

Ozone is a toxic air pollutant that is formed on warm, sunny days when its precursors nitrogen oxides (NO_x) and volatile organic compounds (VOC) react in the presence of sunlight. Because ozone is a regional pollutant, precursor sources both near and far from FLM areas can contribute to ozone formation.

High ozone exposure can harm human health (U.S. EPA, 1996). Ozone is also phytotoxic, causing considerable damage to vegetation throughout the world. Some plant species are more sensitive to ozone than are humans (U.S. EPA, 1996). The primary National Ambient Air Quality Standard (NAAQS) for ozone is designed to protect human health, and the secondary NAAQS is set to achieve protection of the public welfare, including vegetation. The primary and secondary standards for ozone are the same. The new 8-hour, 0.08 ppm NAAQS for ozone is expected to be more protective of vegetation than the 1-hour, 0.12 ppm NAAQS.[1] Attaining and maintaining compliance with the NAAQS is the responsibility of states and EPA rather than the FLMs. FLAG guidelines are not for regulatory purposes, but provide guidance for the FLM to identify ozone impacts on lands they manage.

FLAG recognizes that specific relationships between precursor emissions and ambient ozone concentrations at a FLM area are difficult to quantify. Further, it is difficult to quantify the specific relationship between ambient ozone at a FLM area and vegetation response. Therefore, FLAG has chosen to focus on the effects of ozone on vegetation and the levels of ozone generally known to be phytotoxic in FLM areas as indicators of concern regarding ozone impacts on AQRVs.

The objectives of this chapter are to document information currently known about vegetation response to ozone exposure, and to describe FLM procedures for responding to new source review (NSR) permit applications. If the FLMs have evidence that ozone is adversely impacting an area they manage, they will work to restrict further emissions of ozone precursors until those adverse impacts are mitigated.

b. Ozone Effects on Vegetation

Most ozone effects research has focused on agricultural crops because of the large economic losses that have been documented. Nevertheless, research has identified many native plants in natural ecosystems that are sensitive to ozone (U.S. EPA, 1996). Some of these ozone-sensitive plant species have been used as "bioindicators" of ozone to document phytotoxicity of ozone in the field due to ambient ozone. A listing of key literature describing known ozone effects on native vegetation is provided in Appendix H.

The definitions for ozone injury and damage used by FLMs are based on the classical definitions (for example, see Guderian 1977). Injury is all physical or biological responses to pollutants, such as change in metabolism, reduced photosynthesis, leaf necrosis, premature leaf drop, and chlorosis. Damage is reduction in the intended use or value of the biological or physical resource; for example,

---

[1]The new 8-hour standard is currently being challenged in court and is not yet enforced; the 1-hour standard is still in effect.

economic production, ecological structure and function, aesthetic value, and biological or genetic diversity that may be altered through the impact of pollutants.

Ozone enters plants through leaf stomata. It oxidizes plant tissue, causing changes in biochemical and physiological processes. These biochemical and physiological changes occur within the leaf long before visible necrotic symptoms appear (Guderian *et al.*1985). Plants must expend energy to detoxify ozone and repair injured tissue that could otherwise be used for growth or for maintenance of plant health. The injured plant cells eventually die if detoxification and repair cannot keep up with ozone uptake. The mesophyll cells under the upper epidermis of leaves are the most sensitive to ozone, and those are the first cells to die. The adjacent epidermal cells then die, forming a small black or brown interveinal necrotic lesion that becomes visible on the upper surface of the leaf. These visible lesions most frequently begin to develop on leaves that have just become fully matured, with older leaves on a stem showing increased amounts of injury. These lesions, termed oxidant stipple[2], are quite specific indicators that the plant has been exposed to ozone. Other plant symptoms that can result from exposure to ozone, with or without the presence of oxidant stipple, include chlorosis, premature senescence, and reduced growth. However, these symptoms are non-specific for ozone since other stressors can also cause them to occur. Further, these non-specific symptoms are difficult to quantify in natural ecosystems, although limited data are available from exposure response experiments to estimate growth losses from specific ozone exposures. In general, the only indicator that a FLM has to document that ozone has impacted vegetation is visible symptoms of injury such as oxidant stipple.

In addition to affecting individual plants, ozone can also affect entire ecosystems. Research shows that plants growing in areas with high exposure to ambient ozone may undergo natural selection for ozone tolerance (U.S. EPA, 1996). The final result could be the elimination of the most ozone-sensitive genotypes from the area. Regardless of the amount of ozone exposure, the magnitude of plant response may vary depending on the geographic area because of changes in meteorological and climatic conditions, and differences in plant conditions in space and time. Factors of most importance that influence plant response to ozone are the species/genotype, soil moisture, and nitrogen availability. Other factors influencing plant response to ozone include nutrient status, atmospheric humidity, temperature, solar radiation, phenological stage of development, day length, regional climatic differences, other pollutant interactions, and population/ecosystem interactions (U.S. EPA, 1996).

Ozone-induced physiological changes and/or growth reductions in plants may exist long before necrotic lesions appear on foliage; however, it is very difficult to attribute these effects directly to ozone. Similarly, changes in growth, ecosystem form or function, or biological or genetic diversity caused by ozone are difficult to document in natural ecosystems. Limited data are available regarding injury and growth response to specific ozone exposures. Given the difficulty in determining ozone-induced physiological or growth changes in natural ecosystems, FLMs will utilize as indicators of ozone effects on vegetation (1) symptoms that are clearly ozone induced such as oxidant stipple, and (2) ozone exposures that have been shown to be phytotoxic.

[2]Specific symptoms of ozone injury in some plant species are different. A few species develop white or tan rather than brown or black lesions. This is termed "fleck" or "weather fleck" instead of oxidant stipple. In conifers, ozone causes banding of necrotic and green tissue near the tips of older needles, termed "chlorotic mottle."

c. Recommended Metric to Determine Phytotoxic Ozone Concentrations

Various metrics have been used to relate ozone exposure to plant response. Biologically relevant ozone metrics for plants cannot be directly related to, nor can they be calculated from, the 8-hour NAAQS for ozone. The NAAQS ozone metric does not directly account for peak concentrations, nor does it accumulate exposure, important parameters in any biologically relevant ozone metric. Biologically relevant metrics considered by FLAG include the W126, SUM06, AOT40, and ozone flux. The W126 is an index that uses a sigmoidal weighted function to weight each hourly ozone concentration. The W126 index is determined by summing all the sigmoidal weighted concentrations for a specified time period (Lefohn and Runeckles, 1987). The W126 index was described and used in EPA's *Air Quality Criteria for Ozone and Related Photochemical Oxidants, Vol. II* (U.S. EPA, 1996) to characterize ozone trends. FLMs will use the W126 metric to determine phytotoxic ozone concentrations in FLM areas. The W126 is preferred to other cumulative metrics for a couple of reasons. First, the W126 preferentially weights the peak exposures, whereas other metrics, such as the AOT40 or the SUM06, do not. Second, the W126 accumulates ozone exposures at lower concentrations than does the AOT40 or SUM06. The AOT40 and SUM06 only accumulate concentrations above their particular threshold, *e.g.*, 40 ppb for AOT40 and 60 ppb for SUM06. Phytotoxic effects have been shown to occur at exposure concentrations below 60 ppb (U.S. EPA 1996). The AOT40 metric is commonly used in Europe. Some European scientists recently have concluded that the AOT40 metric is useful for exceedance mapping but not for assessment of biomass loss (Kaerenlampi and Skaerby 1996). Therefore, FLAG does not recommend the AOT40 for FLM assessments.

The SUM06, W126, and AOT40 are ambient ozone exposure parameters, whereas flux is an ozone dose parameter for internal uptake. Flux is determined from ambient ozone concentration at the leaf surface and stomatal conductance. Ozone uptake relates more closely to plant response than does ambient ozone exposure. However, detoxification of ozone once it enters the plant is also an important component of plant response, and measuring uptake alone will not necessarily reflect the potential plant response. A benefit of flux is that it might allow differential weighting of daytime versus nighttime exposure (with daytime being weighted more heavily in most cases). Science has not advanced sufficiently for FLAG to recommend use of flux as a metric for plant response to ozone at this time. However, research on the use of flux as an ozone metric is continuing (Massman *et al.* 2000) and it will be examined for possible future use.

To use the W126 metric, the daily and seasonal time periods of measurement must also be determined. Although most ozone uptake occurs during the day, many plant species can have nighttime stomatal conductance resulting in ozone uptake (Musselman and Minnick 2000). Nighttime uptake is a function of many variables, including species, region (*e.g.*, desert, deciduous forest, etc.), season, and elevation. In addition, many FLM areas, particularly those in mountainous regions, have high nighttime ozone exposures. Further, plants may be more sensitive to ozone at night (Musselman and Minnick 2000). Therefore, FLAG endorses use of a 24-hour time period for the W126 metric.

Plant sensitivity and exposure to ozone will change throughout the growing season. Use of a rolling 90-day cumulative value for the W126 metric would account for changes in exposure over the season. However, some vegetation exposure/response and ozone monitoring data are currently available using 7-month (April through October) seasonal cumulative W126 values. In order to take advantage of this existing information, FLAG will use the April-October time period for the W126 metric.

FLAG recommends that peak concentrations (hourly ozone values greater than 100 ppb or N100) be included as a parameter of measurement in conjunction with the W126 parameter. Experimental evidence confirms that peak concentrations are important (U.S. EPA 1996). Accounting for peak concentrations also provides important information regarding the timing of events and helps determine if a response is due to chronic or acute exposure. Also, the quantitative exposure/growth response information used by FLAG for determination of critical exposure ozone levels was generated from experimentation based on fumigation treatments containing numerous occurrences of high hourly average concentrations. FLAG recognizes that oxidant stipple injury can occur at zero N100 for sensitive plant species; but the N100 should not be used alone as an indicator of sensitivity of vegetation to ozone.

W126 and N100 values for injury and growth loss for selected eastern U.S. vegetation are presented in Table O-1 and Table O-2. Data for Table O-1 were derived under favorable environmental conditions, and report the lowest exposure level treatment where visible ozone symptoms were first observed. Thus, threshold exposure levels for ozone symptom response could be lower than those exposures reported here. Data from Table O-2 were calculated from exposure response relationships for a 10 percent growth loss when plants are grown under favorable environmental conditions. It is recognized that data for other eastern U.S. plant species, and for plant species growing in the Western U.S., are not currently available. However, some additional exposure/response data for other species are available from which these values can be calculated. It is important to note that the critical level for injury or growth loss to vegetation from ozone is highly dependent on plant species and environmental conditions when the plants are exposed. The results obtained in Tables O-1 and O-2 could vary under different combinations of environmental conditions. Additional research under varying environmental conditions and ozone exposures should be conducted.

Table O-1. W126 (ppm-h) and N100 ($\geq$ 0.1 ppm) exposure levels that result in foliar necrotic symptoms for selected plant species (from Lefohn 1998.)

Name	W126	N100
Table mountain pine	20.0	2
Sweetgum	5.6	3
Sycamore	31.2	89
Winged sumac	3.3	5
Black cherry	11.5	10
Tall milkweed	0.3	0
Black-eyed Susan	12.8	50
Dwarf dandelion	0.3	0
Yellow buckeye	4.7	3
Virginia pine	30.0	50
Cutleaf coneflower	5.5	3

Table O-2. W126 (ppm-h) and N100 (≥ 0.1 ppm) exposure levels that resulted in a 10 percent growth loss for selected plant species (from Lefohn 1998.)

Name	W126	N100
Aspen 259	6.4	4
Aspen wild	71.4	243
Black Cherry	6.5	1
Red Maple	85.4	245
Whorled-wood aster	8.2	10
Yellow poplar	14.4	4
Eastern white pine	30.2	66
Sugar maple	44.7	131
Sycamore	15.4	27
Winged sumac	9.7	4

Ambient W126 and N100 values are available for many Class I areas in the eastern U.S., with values soon to be available for additional FLM areas. A table showing representative high and low W126 and N100 values for selected FLM areas is appended to this report (Appendix 3.B). Unfortunately, ambient ozone data are lacking for many western U.S. FLM areas, and large differences in terrain and elevation may limit the use of nearby data.

d. Identification of Ozone Sensitive AQRVs or Sensitive Receptors

FLMs have determined that given the high ecological, aesthetic, and intrinsic value of federal lands, all native species are significant and warrant protection. Ideally, protection efforts would focus on the identification and protection of the most sensitive species in an area. Unfortunately, AQRV identification is limited by incomplete species inventories and/or lack of exposure/response data for most species of native vegetation. Sensitive species identification will improve as more information becomes available. In the meantime, FLAG is providing a preliminary list of sensitive plant species for each Class I area, *i.e.*, those species that have been observed to exhibit ozone symptoms at ambient ozone exposures (Appendix 3.A). Those ambient levels have not necessarily occurred at the specific Class I area where the plants occur. AQRV lists will be available in the Air Synthesis and NRIS-AIR databases (See Section B.4.f. of this report) and will be updated as necessary.

e. Review Process for Sources that Could Affect Ozone Levels or Vegetation in FLM Areas

As mentioned above, NO_x and VOC are ozone precursors. States and the EPA have based ozone control strategies in various parts of the country on the determination of which precursor is most likely to influence the formation of ozone. Information suggests that in areas where ozone formation is driven by VOC emissions, *i.e.*, VOC-limited areas, VOC to NO_x ratios are less than 4:1. In VOC-limited areas, minimizing or reducing VOC emissions is the most effective means of limiting or lowering ozone concentrations. Conversely, in NO_x-limited areas, where VOC to NO_x ratios are greater than 15:1, controlling NO_x emissions is most effective. It is generally thought that most rural areas of the U.S. are NO_x-limited, most or all of the time, with the possible exception of the rural areas of southern California. The FLMs do not have current data to show that all areas are NO_x limited, nor do they consider VOCs to be unimportant as ozone precursors. However, until there is enough information available for FLAG to determine whether ozone formation in each FLM area is primarily limited by NO_x or VOC emissions, we will assume all FLM areas are NO_x-limited and will focus on control of NO_x emissions. Where FLMs have information indicating a specific area is VOC limited, they will shift ozone protection strategy to focus on VOC rather than NO_x emissions.

Source/receptor modeling is required in most NSR permit applications for particulate matter, sulfur dioxide, and nitrogen dioxide. FLAG is aware of attempts by EPA and others to develop dispersion models that can relate emissions from a single source to changes in ozone concentrations. We recognize that there is currently no model available that can provide this kind of single source attribution information for ozone. Nevertheless, because of existing and suspected ozone concerns in a number of FLM areas (*e.g.*, evidence of phytotoxic effects and high ambient concentrations), we will consider ozone effects when reviewing NSR permit applications. However, because single source attribution modeling is possible for both visibility and deposition, FLMs will be more concerned about ozone if modeling indicates NO_x emissions are likely to cause an adverse impact on visibility, soils, and/or surface waters.

The FLMs recognize that oxidant stipple can occur at hourly ozone concentrations that can be considered natural background levels (Singh *et al*. 1978). Many of the high hourly background concentrations can be attributed to stratospheric intrusions or stratospheric mixing in the upper troposphere (Singh *et al*. 1978); but stratospheric intrusions rarely occur in the middle and southern latitudes after May (Singh *et al*. 1980, Wooldridge *et al*. 1997), and thus do not coincide with the major portion of the growing season. However, oxidant stipple has been observed on foliage in the spring when these intrusions can occur. In general, oxidant stipple observed on foliage from June through September cannot be attributed to natural background ozone from stratospheric sources. Low levels of ambient ozone may occasionally occur in the troposphere from non-anthropogenic and non-stratospheric sources.

The occurrence of oxidant stipple necrosis on plant foliage may indicate further ozone induced physiological and growth impacts. Point sources emit precursors that could produce ozone at the FLM area, and increased ozone could induce further injury or damage to vegetation. However, we assume that restriction on increases in ozone precursors will prevent additional ambient ozone and subsequent increases in injury or damage to vegetation in FLM managed areas. It is important that ambient ozone monitoring be conducted by the State or Local air pollution control agency or by the FLM to determine the seasonal ozone exposure.

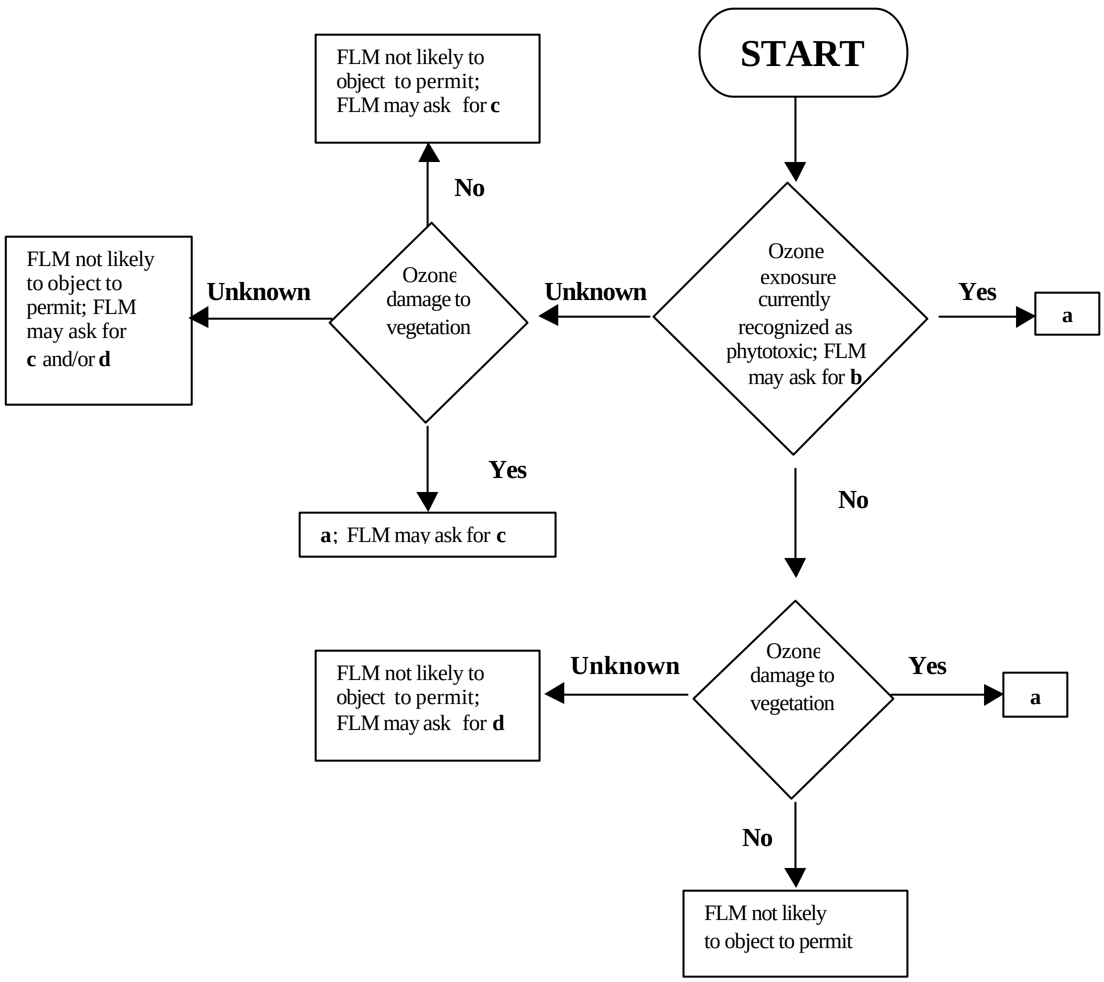
FLM actions or specific requests on a permit application will be based on the existing air pollution situation at the FLM area(s) that may be affected by the source. Some FLMs may rely on growth loss rather than foliar necrosis to make an adverse impact. Each FLM will determine if actions are warranted to limit emissions that might lead to increased ambient ozone, based on the expected impact of ozone in their particular area.

FLM response will depend on whether or not:

1. ozone vegetation effects have been documented in the area (as evidenced by foliar injury or damage to vegetation);
2. ozone exposure levels occurring in the area are high enough that they could affect vegetation (*i.e.*, ozone exposures are at levels shown to be phytotoxic).

Figure O-1 outlines the general FLM process for responding to NSR permit applications based on ozone exposure and vegetation effects at the receptor site. Management decisions regarding acceptance of an existing or future ozone exposure will be area-specific and may differ significantly between agencies, or even regionally within agencies. Each FLM will determine if injury and/or damage are necessary to warrant action, based on the expected impact in the area they manage. The decisions are based on the FLM interpretation of regulations, past experience in the NSR arena, availability of ozone effect exposure/response information for species that occur in the area, and other factors. The FLM will negotiate with the NSR permit applicant and the permitting authority regarding the options listed in Figure O-1.

Figure O-1. FLM response to potential ozone effects from new emissions source.



Items referenced in Figure O-1:

a. The FLM may recommend one or more of the following:
   - That the proposed source use stricter than BACT controls (*e.g.*, Lowest Achievable Emission Rate [LAER]).
   - That the proposed source obtain NO_x emission offsets that will benefit the potentially affected FLM area (as demonstrated by dispersion modeling).
   - That the permitting authority (*i.e.*, state or EPA) conduct regional modeling to identify sources that are contributing significantly to ozone-associated impacts in the FLM area, and that the permitting authority then undertake actions necessary to reduce emissions from those sources (*e.g.*, SIP revision).

b. The applicant calculate the ozone exposure for vegetation (using W126 and N100 metrics) for the affected FLM area(s) where such information is not already available.
c. The permitting authority or applicant fund post-construction ambient ozone monitoring in or near the FLM area.
d. The applicant conduct or fund post-construction ozone effects surveys in the FLM area and/or exposure/response effects research.

Note: “Ozone exposure currently recognized as phytotoxic” is determined based on data from exposure response studies and ambient ozone at the site. The FLM may ask the applicant to calculate the ozone exposure values if these data are not already available. “Ozone damage to vegetation” is determined from field observations at the impacted site.

f. Further Guidance to FLMs

As mentioned above, limited information about ozone exposure/response relationships in plants and lack of an ozone source/receptor model make it difficult to protect FLM areas from the effects of ozone from new sources. However, there are other area-specific gaps in information that also limit protection efforts. It is important for local land managers to attempt to collect the missing information. This section provides guidance specifically to FLMs on what types of data should be collected and how the data could be collected.

Identifying and Monitoring Ozone-sensitive AQRVs

Many FLM areas need more details regarding plant species presence, location, and abundance. FLAG recommends FLMs gather this information, where needed, and refine their lists of area-specific ozone-sensitive plants. FLMs are currently developing lists of sensitive species to crosscheck with the plant species list for their area to determine potential sensitivity to ozone. In the future, the FLMs will place ozone sensitive plant species lists in the NRIS-AIR or Air Synthesis datahe fb08iaMarismatio the plant species he fb0eae sLMsdernessheir afb0nformaentMarksite.

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Ambient Ozone Monitoring

Many FLM areas do not currently have either on-site or nearby ambient ozone monitoring data. FLAG recommends that local FLMs make every effort to collect this information and that they use quality-assured ambient ozone monitoring protocols developed by the EPA and the state air quality agency. Continuous (active) monitoring is preferred since this type of data is necessary to determine compliance with the ozone NAAQS. Continuous monitoring is also necessary to determine the temporal dynamics of ozone exposure for vegetation, and is necessary to calculate the W126 and N100 parameters. Unfortunately, continuous monitoring is expensive and requires electric power that is often not available in or near remote FLM areas. When installing a continuous monitor is not an option, FLAG recommends use of passive monitors. Passive monitors give total exposure loading values (SUM00) for a specified period of time. The data are useful for indicating year-to-year changes in total ozone exposure at an individual site, and for indicating where continuous monitors should be installed. However, FLMs recognize the limitation of passive samplers in relating ozone exposure to plant response.

g. Ozone Air Pollution Web Sites

U.S. EPA ozone information:
http://www.epa.gov/airlinks
http://www.epa.gov gov/oar/oaqps/cleanair.html
http://www.epa.gov/naaqsfin/o3health.htm
http://www.epa.gov/acidrain/castnet

NPS ozone information:
http://www2.nature.nps.gov/ard/gas/network.htm;
http://www2.nature.nps.gov/ard/veginj.htm

Ozone effects research, USDA ARS, North Carolina:
http://www.ces.ncsu.edu/depts/pp/notes/Ozone/ozone.html

Ozone effects research, England:
http://www.ncl.ac.uk/airweb/ozone/ozone.htm

Ozone effects research, Switzerland:
http://www.wsl.ch/forest/risks/wsidb/projects/ozone/ozoneENG.html

Ozone exposure metrics for vegetation:
http://www.asl-associates.com/

Ozone W126 calculator:
http://216.48.37.155/calculator/index.htm

Appendix 3.A: A Preliminary Listing for Selected USDA/FS, NPS, and FWS Class I Areas of Plant Species that have been Shown to be Sensitive Receptors for Ozone.

1. USDA/FS CLASS I WILDERNESS AREAS

Alabama

Sipsey

- Black Cherry *Prunus serotina*
- Blackberry *Rubus canadensis*
- Sweetgum *Liquidambar styraciflua*
- Tulip Poplar *Liriodendron tulipifera*

Arkansas

Upper Buffalo

- Blackberry *Rubus canadensis*

Arizona

Chiricahua

- Serviceberry *Amelanchier alnifola*
- Chokecherry *Prunus virginiana*
- Globemallow *Sphaeralcea*
- Ponderosa Pine *Pinus ponderosa*
- Skunkbush *Rhus trilobata*

Galiuro

- Serviceberry *Amelanchier alnifola*
- Chokecherry *Prunus virginiana*
- Globemallow *Sphaeralcea*
- Ponderosa Pine *Pinus ponderosa*
- Skunkbush *Rhus trilobata*

Mazatzal

- Aspen *Populus tremuloides*
- Ponderosa Pine *Pinus ponderosa*
- Skunkbush *Rhus trilobata*

Mount Baldy

- Arizona Willow *Salix*
- Ponderosa Pine *Pinus ponderosa*
- Western White Pine *Pinus monticola*

Pine Mountain

- Aspen *Populus tremuloides*
- Ponderosa Pine *Pinus ponderosa*
- Skunkbush *Rhus trilobata*

Sierra Ancha

- Aspen *Populus tremuloides*
- Ponderosa Pine *Pinus ponderosa*
- Skunkbush *Rhus trilobata*

Superstition

- Aspen *Populus tremuloides*
- Ponderosa Pine *Pinus ponderosa*
- Skunkbush *Rhus trilobata*

Sycamore Canyon

- Aspen *Populus tremuloides*
- Ponderosa Pine *Pinus ponderosa*
- Skunkbush *Rhus trilobata*

California

Agua Tibia

Jeffrey Pine *Pinus jeffreyi*
Ponderosa Pine *Pinus ponderosa*
Western White Pine *Pinus monticola*

Ansel Adams

Jeffrey Pine *Pinus jeffreyi*
Limber Pine *Pinus flexilis*
Lodgepole Pine *Pinus contorta*
Ponderosa Pine *Pinus ponderosa*
Western White Pine *Pinus monticola*

Caribou

Limber Pine *Pinus flexilis*
Lodgepole Pine *Pinus contorta*

Cucamonga

Jeffrey Pine *Pinus jeffreyi*
Ponderosa Pine *Pinus ponderosa*
Western White Pine *Pinus monticola*

Desolation

Limber Pine *Pinus flexilis*
Lodgepole Pine *Pinus contorta*

Dome Land

Jeffrey Pine *Pinus jeffreyi*
Limber Pine *Pinus flexilis*
Lodgepole Pine *Pinus contorta*
Ponderosa Pine *Pinus ponderosa*
Western White Pine *Pinus monticola*

Emmigrant

Jeffrey Pine *Pinus jeffreyi*
Limber Pine *Pinus flexilis*
Ponderosa Pine *Pinus ponderosa*

Hoover

Ponderosa Pine *Pinus ponderosa*

John Muir

Jeffrey Pine *Pinus jeffreyi*
Limber Pine *Pinus flexilis*
Lodgepole Pine *Pinus contorta*
Ponderosa Pine *Pinus ponderosa*
Western White Pine *Pinus monticola*

Kaiser

Jeffrey Pine *Pinus jeffreyi*
Limber Pine *Pinus flexilis*
Lodgepole Pine *Pinus contorta*
Ponderosa Pine *Pinus ponderosa*
Western White Pine *Pinus monticola*

Marble Mountain

Jeffrey Pine *Pinus jeffreyi*
Limber Pine *Pinus flexilis*
Lodgepole Pine *Pinus contorta*
Ponderosa Pine *Pinus ponderosa*
Western White Pine *Pinus monticola*

Mokelumme

Jeffrey Pine *Pinus jeffreyi*
Limber Pine *Pinus flexilis*
Lodgepole Pine *Pinus contorta*
Ponderosa Pine *Pinus ponderosa*
Western White Pine Pinus *monticola*

San Gorgonio

Jeffrey Pine *Pinus jeffreyi*
Limber Pine *Pinus flexilis*
Lodgepole Pine *Pinus contorta*
Ponderosa Pine *Pinus ponderosa*
Western White Pine *Pinus monticola*

San Jacinto

Jeffrey Pine *Pinus jeffreyi*
Limber Pine *Pinus flexilis*
Lodgepole Pine *Pinus contorta*
Ponderosa Pine *Pinus ponderosa*
Western White Pine *Pinus monticola*

San Rafael

Jeffrey Pine *Pinus jeffreyi*
Ponderosa Pine *Pinus ponderosa*
Western White Pine *Pinus monticola*

South Warner

Jeffrey Pine *Pinus jeffreyi*
Limber Pine *Pinus flexilis*
Lodgepole Pine *Pinus contorta*
Ponderosa Pine *Pinus ponderosa*
Western White Pine *Pinus monticola*

Thousand Lakes

Jeffrey Pine *Pinus jeffreyi*
Limber Pine *Pinus flexilis*
Lodgepole Pine *Pinus contorta*
Ponderosa Pine *Pinus ponderosa*
Western White Pine *Pinus monticola*

Yolla Bolly - Middle Eel

Jeffrey Pine *Pinus jeffreyi*
Limber Pine *Pinus flexilis*
Lodgepole Pine *Pinus contorta*
Ponderosa Pine *Pinus ponderosa*
Western White Pine *Pinus monticola*

Colorado

Eagles Nest

Subalpine fir *Abies lasiocarpa*
White clover *Trifolium repens*
Saskatoon serviceberry *Amelanchier alnifolia*
Sagebrush *Artemesia sp*
Trembling aspen *Populus tremuloides*
Chockcherry *Prunus vierginiana*
Thimbleberry *Rubus parviflorus*
Squawberry *Rhus trilobata*
Huckleberry *Vaccinium sp.*

Flat Tops

Subalpine fir *Abies lasiocarpa*
Boxelder *Acer negundo*
Saskatoon serviceberry *Amelanchier alnifolia*
Sagebrush *Artemesia sp*
Trembling aspen *Populus tremuloides*
Chockcherry *Prunus vierginiana*
Thimbleberry *Rubus parviflorus*
Squawberry *Rhus trilobata*
Huckleberry *Vaccinium sp.*

Maroon Bells – Snowmass

White fir *Abies concolor*
Subalpine fir *Abies lasiocarpa*
Sagebrush *Artemesia sp.*
Trembling aspen *Populus tremuloides*

Mount Zirkel

Subalpine fir *Abies lasiocarpa*
Saskatoon serviceberry *Amelanchier alnifolia*
Sagebrush *Artemesia sp*
Trembling aspen *Populus tremuloides*
Chockcherry *Prunus vierginiana*
Thimbleberry *Rubus parviflorus*
Squawberry *Rhus trilobata*
Huckleberry *Vaccinium sp.*

Rawah

White fir *Abies concolor*
Subalpine fir *Abies lasiocarpa*
Boxelder *Acer negundo*
Saskatoon serviceberry *Amelanchier alnifolia*
Sagebrush *Artemesia sp*
Trembling aspen *Populus tremuloides*
Chockcherry *Prunus vierginiana*
Thimbleberry *Rubus parviflorus*
Squawberry *Rhus trilobata*
Huckleberry *Vaccinium sp.*

Weminuche

White fir *Abies concolor*
Subalpine fir *Abies lasiocarpa*
Saskatoon serviceberry *Amelanchier alnifolia*
Sagebrush *Artemesia sp*
Trembling aspen *Populus tremuloides*
Chockcherry *Prunus vierginiana*
Thimbleberry *Rubus parviflorus*
Huckleberry *Vaccinium sp.*

West Elk

White fir *Abies concolor*
Subalpine fir *Abies lasiocarpa*
Boxelder *Acer negundo*
Saskatoon serviceberry *Amelanchier alnifolia*
Sagebrush *Artemesia sp*
Hybrid poplar *Populus deloides x trichocarpa*
Ninebark *Pysocarpus sp.*
Chockcherry *Prunus vierginiana*
Thimbleberry *Rubus parviflorus*
Squawberry *Rhus trilobata*
Huckleberry *Vaccinium sp.*

Florida

Bradwell Bay

Blackberry *Rubus canadensis*
Staghorn Sumac *Rhus typhina*
Sweetgum *Liquidambar styraciflua*
Tulip Poplar *Liriodendron tulipifera*

<u>Georgia</u>
<u>Cohutta</u>
Black Cherry *Prunus serotina*
Blackberry *Rubus canadensis*
Sweetgum *Liquidambar styraciflua*
Tulip Poplar *Liriodendron tulipifera*
<u>Idaho</u>
<u>Sawtooth</u>
Ponderosa Pine *Pinus ponderosa*

<u>Minnesota</u>
<u>Boundary Waters Canoe Area</u>
Aspen *Populus tremuloides*
Chokecherry *Prunus virginiana*
Eastern White Pine *Pinus strobus*

<u>Missouri</u>
<u>Hercules-Glades</u>
Black Cherry *Prunus serotina*
Elderberry *Sambucus canadensis*
Milkweed *Asclepias syriaca*
Tulip Poplar *Liriodendron tulipifera*
White Ash *Fraxinus americana*

<u>Nevada</u>
<u>Jarbridge</u>
Ponderosa Pine *Pinus ponderosa*

<u>New Hampshire</u>
<u>Great Gulf</u>
Black Cherry *Prunus serotina*
Elderberry *Sambucus canadensis*
Milkweed *Asclepias syriaca*
Tulip Poplar *Liriodendron tulipifera*
White Ash *Fraxinus americana*
<u>Presidential Range - Dry River</u>
Black Cherry *Prunus serotina*
Elderberry *Sambucus canadensis*
Milkweed *Asclepias syriaca*
Red Spruce *Picea rubens*
White Ash *Fraxinus americana*

<u>North Carolina</u>
<u>Joyce Kilmer - Slickrock</u>
American Sycamore *Platinus occidentalis*
Black Cherry *Prunus serotina*
Blackberry *Rubus canadensis*
Elderberry *Sambucus canadensis*
Flowering Dogwood *Cornus florida*
Pin Cherry *Prunus pensylvanica*
Poison Ivy *Rhus radicans*
Red Maple *Acer rubrum*
Red Oak *Quercus rubra*
Sassafrass *Sassafras albidum*
Sweetgum *Liquidambar styraciflua*
Tulip Poplar *Liriodendron tulipifera*
White Ash *Fraxinus americana*
Eastern White Pine *Pinus strobus*

Linville Gorge

American Sycamore *Platinus occidentalis*
Black Cherry *Prunus serotina*
Blackberry *Rubus canadensis*
Flowering Dogwood *Cornus florida*
Red Maple *Acer rubrum*
Red Oak *Quercus rubra*
Sassafrass *Sassafras albidum*
Sweetgum *Liquidambar styraciflua*
Tulip Poplar *Liriodendron tulipifera*
Eastern White Pine *Pinus strobus*

Shining Rock

Black Cherry *Prunus serotina*
Black-Eyed Susan *Rudbeckia hirta*
Blackberry *Rubus canadensis*
Chokecherry *Prunus virginiana*
Flowering Dogwood *Cornus florida*
Milkweed *Asclepias syriaca*
Poison Ivy *Rhus radicans*
Red Oak *Quercus rubra*
Sassafrass *Sassafras albidum*
Tulip Poplar *Liriodendron tulipifera*
White Ash *Fraxinus americana*
Eastern White Pine *Pinus strobus*

Oregon*

Diamond Peak

Western Serviceberry *Amelancier alnifolia*
Quaking Aspen *Populus tremuloides*
Scouler Willow *Salix scouleriana*
Thin-leaved Huckleberry *Vaccinium membranaceum*
Red Alder *Alnus rubra*
Mountain Ash *Sorbus sitchensis*
Black Twin-berry *Lonicera involucrata*
Stink Currant Ribes bracteosum

Eagle Cap

Western Serviceberry *Amelancier alnifolia*
Ponderosa Pine *Pinus ponderosa*
Quaking Aspen *Populus tremuloides*
Scouler Willow *Salix scouleriana*
Thin-leaved Huckleberry *Vaccinium membranaceum*
Mountain Ash *Sorbus sitchensis*
Black Twin-berry *Lonicera involucrata*

Gearhart Mountain

Western Serviceberry *Amelancier alnifolia*
Quaking Aspen *Populus tremuloides*
Scouler Willow *Salix scouleriana*
Thin-leaved Huckleberry *Vaccinium membranaceum*
Mountain Ash *Sorbus sitchensis*
Black Twin-berry *Lonicera involucrata*

*Plant species listed for Oregon have been identified as ozone sensitive in laboratory fumigations. Ozone injury to some of these species has not been verified in the field.

Hells Canyon

Western Serviceberry *Amelancier alnifolia*
Ponderosa Pine *Pinus ponderosa*
Quaking Aspen *Populus tremuloides*
Scouler Willow *Salix scouleriana*
Black Twin-berry *Lonicera involucrata*
Mallow Ninebark *Physocarpus malvaceus*
Black Cottonwood *Populus trichocarpa*

Kalmiopsis

Western Serviceberry *Amelancier alnifolia*
Scouler Willow *Salix scouleriana*
Thin-leaved Huckleberry *Vaccinium membranaceum*
Mountain Ash *Sorbus sitchensis*
Black Twin-berry *Lonicera involucrata*

Mount Hood

Western Serviceberry *Amelancier alnifolia*
Pacific ninebark *Physocarpus capitatus*
Quaking Aspen *Populus tremuloides*
Scouler Willow *Salix scouleriana*
Thin-leaved Huckleberry *Vaccinium membranaceum*
Red Alder *Alnus rubra*
Mountain Ash *Sorbus sitchensis*
Black Twin-berry *Lonicera involucrata*
Black Cottonwood *Populus trichocarpa*
Stink Currant *Ribes bracteosum*

Mount Jefferson

Western Serviceberry *Amelancier alnifolia*
Quaking Aspen *Populus tremuloides*
Scouler Willow *Salix scouleriana*
Thin-leaved Huckleberry *Vaccinium membranaceum*
Red Alder *Alnus rubra*
Mountain Ash *Sorbus sitchensis*
Black Twin-berry *Lonicera involucrata*
Black Cottonwood *Populus trichocarpa*
Stink Currant *Ribes bracteosum*

Mount Washington

Western Serviceberry *Amelancier alnifolia*
Scouler Willow *Salix scouleriana*
Thin-leaved Huckleberry *Vaccinium membranaceum*
Red Alder *Alnus rubra*
Mountain Ash *Sorbus sitchensis*
Black Twin-berry *Lonicera involucrata*
Stink Currant *Ribes bracteosum*

Mountain Lakes

Western Serviceberry *Amelancier alnifolia*
Pacific ninebark *Physocarpus capitatus*
Ponderosa Pine *Pinus ponderosa*
Quaking Aspen *Populus tremuloides*
Scouler Willow *Salix scouleriana*
Thin-leaved Huckleberry *Vaccinium membranaceum*
Red Alder *Alnus rubra*
Mountain Ash *Sorbus sitchensis*
Black Twin-berry *Lonicera involucrata*
Black Cottonwood *Populus trichocarpa*

Strawberry Mountain

Western Serviceberry *Amelancier alnifolia*
Ponderosa Pine *Pinus ponderosa*
Quaking Aspen *Populus tremuloides*
Scouler Willow *Salix scouleriana*
Thin-leaved Huckleberry *Vaccinium membranaceum*
Mountain Ash *Sorbus sitchensis*
Black Twin-berry *Lonicera involucrata*

Three Sisters

Western Serviceberry *Amelancier alnifolia*
Pacific ninebark *Physocarpus capitatus*
Ponderosa Pine *Pinus ponderosa*
Quaking Aspen *Populus tremuloides*
Scouler Willow *Salix scouleriana*
Thin-leaved Huckleberry *Vaccinium membranaceum*
Mountain Ash *Sorbus sitchensis*
Black Twin-berry *Lonicera involucrata*

Vermont

Lye Brook

Black Cherry *Prunus serotina*
Elderberry *Sambucus canadensis*
Milkweed *Asclepias syriaca*
Red Spruce *Picea rubens*
White Ash *Fraxinus americana*

Virginia

James River Face

Black Cherry *Prunus serotina*
Blackberry *Rubus canadensis*
Chokecherry *Prunus virginiana*
Flowering Dogwood *Cornus florida*
Milkweed *Asclepias syriaca*
Poison Ivy *Rhus radicans*
Red Oak *Quercus rubra*
Sassafrass *Sassafras albidum*
Sweetgum *Liquidambar styraciflua*
Tulip Poplar *Liriodendron tulipifera*
White Ash *Fraxinus americana*
Eastern White Pine *Pinus strobus*

Washington*

Alpine Lakes

Western Serviceberry *Amelancier alnifolia*
Scouler Willow *Salix scouleriana*
Thin-leaved Huckleberry *Vaccinium membranaceum*
Red Alder *Alnus rubra*
Mountain Ash *Sorbus sitchensis*
Black Twin-berry *Lonicera involucrata*
Stink Currant *Ribes bracteosum*

*Plant species listed for Washington have been identified as ozone sensitive in laboratory fumigations. Ozone injury to some of these species has not been verified in the field.

Glacier Peak

Western Serviceberry *Amelancier alnifolia*
Pacific ninebark *Physocarpus capitatus*
Scouler Willow *Salix scouleriana*
Thin-leaved Huckleberry *Vaccinium membranaceum*
Red Alder *Alnus rubra*
Mountain Ash *Sorbus sitchensis*
Black Twin-berry *Lonicera involucrata*
Black Cottonwood *Populus trichocarpa*
Stink Currant *Ribes bracteosum*

Goat Rocks

Western Serviceberry *Amelancier alnifolia*
Pacific ninebark *Physocarpus capitatus*
Scouler Willow *Salix scouleriana*
Thin-leaved Huckleberry *Vaccinium membranaceum*
Red Alder *Alnus rubra*
Mountain Ash *Sorbus sitchensis*
Black Twin-berry *Lonicera involucrata*
Black Cottonwood *Populus trichocarpa*
Stink Currant *Ribes bracteosum*

Mount Adams

Western Serviceberry *Amelancier alnifolia*
Pacific ninebark *Physocarpus capitatus*
Quaking Aspen *Populus tremuloides*
Scouler Willow *Salix scouleriana*
Thin-leaved Huckleberry *Vaccinium membranaceum*
Red Alder *Alnus rubra*
Mountain Ash *Sorbus sitchensis*
Black Twin-berry *Lonicera involucrata*
Black Cottonwood *Populus trichocarpa*
Stink Currant *Ribes bracteosum*

Paysayten

Western Serviceberry *Amelancier alnifolia*
Quaking Aspen *Populus tremuloides*
Scouler Willow *Salix scouleriana*
Thin-leaved Huckleberry *Vaccinium membranaceum*
Mountain Ash *Sorbus sitchensis*
Black Twin-berry *Lonicera involucrata*

West Virginia

Dolly Sods

Black Cherry *Prunus serotina*
Elderberry *Sambucus canadensis*
Milkweed *Asclepias syriaca*
Tulip Poplar *Liriodendron tulipifera*
White Ash *Fraxinus americana*

Otter Creek

Black Cherry *Prunus serotina*
Elderberry *Sambucus canadensis*
Milkweed *Asclepias syriaca*
Red Spruce *Picea rubens*
Tulip Poplar *Liriodendron tulipifera*
White Ash *Fraxinus americana*

<u>Wisconsin</u>

<u>Rainbow Lake</u>

Aspen *Populus tremuloides*
Chokecherry *Prunus virginiana*
Eastern White Pine *Pinus strobus*

<u>Wyoming</u>

<u>Bridger</u>

Ponderosa Pine *Pinus ponderosa*

<u>Fitzpatrick</u> (probable species)

Subalpine fir *Abies lasiocarpa*
Boxelder *Acer negundo*
Serviceberry *Amelanchier alnifolia*
Sagebrush *Artemesia sp.*
Hybrid poplar *Populus deloides x trichocarpa*
Trembling aspen *Populus tremuloides*
Chockcherry *Prunus vierginiana*
Ninebark *Pysocarpus sp.*
Thimbleberry *Rubus parviflorus*
Squawberry *Rhus trilobata*
Huckleberry *Vaccinium sp.*

<u>North Absoroka</u> (probable species)

Subalpine fir *Abies lasiocarpa*
Boxelder *Acer negundo*
Serviceberry *Amelanchier alnifolia*
Sagebrush *Artemesia sp.*
Hybrid poplar *Populus deloides x trichocarpa*
Trembling aspen *Populus tremuloides*
Chockcherry *Prunus vierginiana*
Ninebark *Pysocarpus sp.*
Thimbleberry *Rubus parviflorus*
Squawberry *Rhus trilobata*
Huckleberry *Vaccinium sp.*

<u>Teton</u>

Ponderosa Pine *Pinus ponderosa*

<u>Washakie</u> (probable species)

Subalpine fir *Abies lasiocarpa*
Boxelder *Acer negundo*
Serviceberry *Amelanchier alnifolia*
Sagebrush *Artemesia sp.*
Hybrid poplar *Populus deloides x trichocarpa*
Trembling aspen *Populus tremuloides*
Chockcherry *Prunus vierginiana*
Ninebark *Pysocarpus sp.*
Thimbleberry *Rubus parviflorus*
Squawberry *Rhus trilobata*
Huckleberry *Vaccinium sp.*

2. NPS CLASS I AREAS

Alaska

Denali NP

Quaking aspen *Populus tremuloides*
Black poplar *Populus balsamifera*

Arizona

Chiricahua NM

Arizona pine *Pinus ponderosa*
Skunkbush *Rhus trilobata*
White stem blazingstar *Mentzelia albicaulis*
Black cherry *Prunus serotina*
White clover *Trifolium repens*

Grand Canyon NP

Cottonwood *Populus fremontii*
Ponderosa pine *Pinus ponderosa*
Quaking aspen *Populus tremuloides*
Single-leaf ash *Fraxinus anomala*
Skunkbush *Rhus trilobata*
Serviceberry *Amelanchier alnifolia*
White stem blazingstar *Mentzelia albicaulis*
Smooth desert dandelion *Malacothrix glabrata*
Desert dandelion *Malacothrix glabrata*
White clover *Trifolium repens*

Petrified Forest NP

Skunkbush *Rhus trilobata*
Cheat grass *Bromus tectorum*
Red-stem stork's bill *Erodium cicutarium*
Perrenial rye grass *Lolium perenne*
White stem blazingstar *Mentzelia albicaulis*

Saguaro NP

Ponderosa pine *Pinus ponderosa*
Skunkbush *Rhus trilobata*
Quaking aspen *Populus tremuloides*

California

Joshua Tree NP

Single-leaf ash *Fraxinus anomala*
Skunkbush *Rhus trilobata*
White stem blazingstar *Mentzelia albicaulis*

Kings Canyon NP

Jeffrey pine *Pinus jeffreyi*
Ponderosa pine *Pinus ponderosa*
Twinberry *Lonicera involucrata*
Quaking aspen *Populus tremuloides*
Chokecherry *Prunus virginiana*
Skunkbush *Rhus trilobata*
Butterweed groundsel *Senecio serra*
White clover *Trifolium repens*
Black poplar *Populus balsamifera trichocarpa*

Lassen Volcanic NP

Skunkbush *Rhus trilobata*
Chokecherry *Prunus virginiana*
Ponderosa pine *Pinus ponderosa*
White clover *Trifolium repens*
Jeffrey pine *Pinus jeffreyi*

Lava Beds NM

Chokecherry *Prunus virginiana*
Ponderosa pine *Pinus ponderosa*
Quaking aspen *Populus tremuloides*
Jeffrey pine *Pinus jeffreyi*

Point Reyes National Seashore

Ledebour's honeysuckle *Lonicera involucrata*
White clover *Trifolium repens*

Redwood NP

White clover *Trifolium repens*
Black poplar *Populus balsamifera trichocarpa*
Chokecherry *Prunus virginiana*
Jeffrey pine *Pinus jeffreyi*

Sequoia NP

Jeffrey pine *Pinus jeffreyi*
Ponderosa pine *Pinus ponderosa*
Twinberry *Lonicera involucrata*
Quaking aspen *Populus tremuloides*
Chokecherry *Prunus virginiana*
Skunkbush *Rhus trilobata*
Butterweed groundsel *Senecio serra*
White clover *Trifolium repens*
Black poplar *Populus balsamifera trichocarpa*

Yosemite NP

Ponderosa pine *Pinus ponderosa*
White clover *Trifolium repens*
Skunkbush *Rhus trilobata*
Twinberry honeysuckle *Lonicera involucrata*
Chokecherry *Prunus virginiana*

Colorado

Black Canyon of the Gunnison NP

Serviceberry *Amelanchier alnifolia*
Quaking aspen *Populus tremuloides*
Skunkbush *Rhus trilobata*
White clover *Trifolium repens*
Chokecherry *Prunus virginiana*

Great Sand Dunes NM

Ponderosa pine *Pinus ponderosa*
Quaking aspen *Populus tremuloides*
Serviceberry *Amelanchier alnifolia*
Mountain ninebark *Physocarpus monogynus*
Skunkbush *Rhus trilobata*
White stem blazingstar *Mentzelia albicaulis*
White clover *Trifolium repens*

Mesa Verde NP

Ponderosa pine *Pinus ponderosa*
Spreading dogbane *Apocynum androsaemifolium*
Box elder *Acer negundo*
Cheat grass *Bromus tectorum*
Poison ivy *Toxicodendron radicans*
Skunkbush *Rhus trilobata*
Serviceberry *Amelanchier alnifolia*
Quaking aspen *Populus tremuloides*
White stem blazingstar *Mentzelia albicaulis*
White clover *Trifolium repens*

<u>Rocky Mountain NP</u>

Wild strawberry *Fragaria virginiana*
Mountain ninebark *Physocarpus monogyna*
Ponderosa pine *Pinus ponderosa*
Balsam poplar *Populus balsamifera*
Quaking aspen *Populus tremuloides*
Chokecherry *Prunus virginiana*
White clover *Trifolium repens*

<u>Hawaii</u>

<u>Haleakala NP</u>

Ponderosa pine *Pinus ponderosa*
White clover *Trifolium repens*

<u>Hawaii Volcanoes NP</u>

White clover *Trifolium repens*

<u>Idaho</u>

<u>Craters of the Moon NM</u>

Black poplar *Populus balsamifera trichocarpa*
Quaking aspen *Populus tremuloides*

<u>Kentucky</u>

<u>Mammoth Cave NP</u>

Yellow-poplar *Liriodendron tulipifera*
Red maple *Acer rubrum*
Poke milkweed *Asclepias exaltata*
American sycamore *Platanus occidentalis*
Black cherry *Prunus serotina*
Black-eyed susan *Rudbeckia hirta*
Cutleaf coneflower *Rudbeckia laciniata*
Sassafras *Sassafras albidum*
Green ash *Fraxinus pennsylvanica*
White clover *Trifolium repens*

<u>Maine</u>

<u>Acadia NP</u>

Broad-leaf aster *Aster macrophyllus*
Black cherry *Prunus serotina*
Quaking aspen *Populus tremuloides*
White ash *Fraxinus americana*
Spreading dogbane *Apocynum androsaemiolium*

<u>Michigan</u>

<u>Isle Royale NP</u>

Common snowberry *Symphoricarpos albus*
Quaking aspen *Populus tremuloides*
Twinberry honeysuckle *Lonicera involucrata*
Black poplar *Populus balsamifera*
White clover *Trifolium repens*
Red maple *Acer rubrum*
Chokecherry *Prunus virginiana*
Bigleaf aster *Aster macrophyllus*
Paper birch *Betula papyrifera*

Minnesota

Voyageurs NP

- Green ash *Fraxinus pennsylvanica*
- Quaking aspen *Populus tremuloides*
- Chokecherry *Prunus virginiana*
- White clover *Trifolium repens*
- Snowberry *Symphoricarpos albus*
- Paper birch *Betula papyrifera*
- Common milkweed *Asclepias syriaca*
- Black poplar *Populus balsamifera*
- Red maple *Acer rubrum*

Montana

Glacier NP

- Paper birch *Betula papyrifera*
- Wild strawberry *Fragaria virginiana*
- Twinberry *Lonicera involucrata*
- Rock-spiraea *Holodiscus discolor*
- Ponderosa pine *Pinus ponderosa*
- Black poplar *Populus balsamifera trichocarpa*
- Quaking aspen *Populus tremuloides*
- Chokecherry *Prunus virginiana*
- Snowberry *Symphoricarpos albus*
- White clover *Trifolium repens*

New Mexico

Bandelier NM

- Ponderosa pine *Pinus ponderosa*
- Quaking aspen *Populus tremuloides*
- Skunkbush *Rhus trilobata*
- White clover *Trifolium repens*

Carlsbad Caverns NP

- Ponderosa pine *Pinus ponderosa*
- Fremont's cottonwood *Populus fremontii*
- Quaking aspen *Populus tremuloides*
- White stem blazingstar *Mentzelia albicaulis*
- Black cherry *Prunus serotina*

North Carolina/Tennessee

Great Smoky Mountains NP

- Yellow-poplar *Liriodendron tulipifera*
- Red maple *Acer rubrum*
- Tall milkweed *Asclepias exaltata*
- Table-mountain pine *Pinus pungens*
- American sycamore *Platanus occidentalis*
- Black cherry *Prunus serotina*
- Winged sumac *Rhus copallina*
- Black-eyed susan *Rudbeckia hirta*
- Cutleaf coneflower *Rudbeckia laciniata*
- Crown-beard *Verbesina occidentalis*
- Sassafras *Sassafras albidum*

<u>North Dakota</u>

<u>Theodore Roosevelt NP</u>

Paper birch *Betula papyrifera*
Wild strawberry *Fragaria virginiana*
Ponderosa pine *Pinus ponderosa*
Quaking aspen *Populus tremuloides*
Chokecherry *Prunus virginiana*
White clover *Trifolium repens*

<u>Oregon</u>

<u>Crater Lake NP</u>

Ponderosa pine *Pinus ponderosa*
Black poplar *Populus balsamifera trichocarpa*
Quaking aspen *Populus tremuloides*
Lodgepole pine *Pinus contorta*

<u>South Dakota</u>

<u>Badlands NP</u>

Green ash *Fraxinus pennsylvanica*
Ponderosa pine *Pinus ponderosa*
Chokecherry *Prunus virginiana*
Snowberry *Symphoricarpos albus*
Western wormwood *Artemisia ludoviciana*

<u>Wind Cave NP</u>

Wild strawberry *Fragaria virginiana*
Green ash *Fraxinus pennsylvanica*
Quaking aspen *Populus tremuloides*
Ponderosa pine *Pinus ponderosa*
Chokecherry *Prunus virginiana*

<u>Texas</u>

<u>Big Bend NP</u>

Ponderosa pine *Pinus ponderosa*
Quaking aspen *Populus tremuloides*
Black cherry *Prunus serotina*
Skunkbush *Rhus trilobata*

<u>Guadalupe Mountains NP</u>

Ponderosa pine *Pinus ponderosa*
Quaking aspen *Populus tremuloides*
Black cherry *Prunus serotina*
White stem blazingstar *Mentzelia albicaulis*
Chokecherry *Prunus virginiana*

<u>Utah</u>

<u>Arches NP</u>

Cottonwood *Populus fremontii*
Single-leaf ash *Fraxinus anomala*
Skunkbush *Rhus trilobata*
White stem blazingstar *Mentzelia albicaulis*

<u>Bryce Canyon NP</u>

Ponderosa pine *Pinus ponderosa*
Quaking aspen *Populus tremuloides*
Skunkbush *Rhus trilobata*
White clover *Trifolium repens*

Canyonlands NP

Cottonwood *Populus fremontii*
Single-leaf ash *Fraxinus anomala*
Serviceberry *Amelanchier alnifolia*
Quaking aspen *Populus tremuloides*
White stem blazingstar *Mentzelia albicaulis*

Capitol Reef NP

Ponderosa pine *Pinus ponderosa*
Quaking aspen *Populus tremuloides*
Cottonwood *Populus fremontii*
Single-leaf ash *Fraxinus anomala*
Serviceberry *Amelanchier alnifolia*
Skunkbush *Rhus trilobata*
White stem blazingstar *Mentzelia albicaulis*
White clover *Trifolium repens*
Smooth desert dandelion *Malacothrix glabrata*

Zion NP

Cottonwood *Populus fremontii*
Ponderosa pine *Pinus ponderosa*
Quaking aspen *Populus tremuloides*
Skunkbush *Rhus trilobata*
Serviceberry *Amelanchier alnifolia*
White stem blazingstar *Mentzelia albicaulis*
White clover *Trifolium repens*

Virginia

Shenandoah NP

Black cherry *Prunus serotina*
Quaking aspen *Populus tremuloides*
White ash *Fraxinus americana*
Common milkweed *Asclepias syriaca*
Yellow-poplar *Liriodendron tulipifera*
American sycamore *Platanus occidentalis*
White clover *Trifolium repens*

Washington

Mount Rainier NP

Ponderosa pine *Pinus ponderosa*
Black poplar *Populus balsamifera trichocarpa*
Quaking aspen *Populus tremuloides*
Twinberry *Lonicera involucrata*
Serviceberry *Amelanchier alnifolia*
Snowberry *Symphoricarpos albus*

North Cascades NP

Ponderosa pine *Pinus ponderosa*
Black poplar *Populus balsamifera trichocarpa*
Paper birch *Betula papyrifera*
Box elder *Acer negundo*
Twinberry *Lonicera involucrata*
Serviceberry *Amelanchier alnifolia*
Snowberry *Symphoricarpos albus*

Olympic NP

Black poplar *Populus balsamifera trichocarpa*
Twinberry *Lonicera involucrata*
Serviceberry *Amelanchier alnifolia*
Snowberry *Symphoricarpos* albus

<u>Wyoming</u>

<u>Grand Teton NP</u>

Wild strawberry *Fragaria virginiana*
Twinberry *Lonicera involucrata*
Black poplar *Populus balsamifera trichocarpa*
Quaking aspen *Populus tremuloides*
Chokecherry *Prunus virginiana*
Skunkbush *Rhus trilobata*
Bitterweed groundsel *Senecio serra*
White clover *Trifolium repens*

<u>Yellowstone NP</u>

Wild strawberry *Fragaria virginiana*
Twinberry *Lonicera involucrata*
White stem blazingstar *Mentzelia albicaulis*
Black poplar *Populus balsamifera trichocarpa*
Quaking aspen *Populus tremuloides*
Chokecherry *Prunus virginiana*
Skunkbush *Rhus trilobata*
Butterweed groundsel *Senecio serra*
White clover *Trifolium repens*

3. FWS CLASS I WILDERNESS AREAS

Florida

Chassahowitzka

Eastern redbud *Cercis canadensis*
Sweetgum *Liquidambar styraciflua*
Loblolly pine *Pinus taeda*
Black cherry *Prunus serotina*
Dwarf sumac *Rhus copallina*
Blackeyed Susan *Rudbeckia hirta*

Georgia

Okefenokee

American sycamore *Platanus occidentalis*
Black cherry *Prunus serotina*
Dwarf sumac *Rhus copallina*
Eastern poison ivy *Toxicodendron radicans*
Eastern redbud *Cercis canadensis*
Flowering dogwood *Cornus florida*
Loblolly pine *Pinus taeda*
Red maple *Acer rubrum*
Sweetgum *Liquidambar styraciflua*
Tree-of-heaven *Ailanthus altissima*
Virginia creeper *Parthenocissus quinquefolia*

Maine

Moosehorn

Spreading dogbane *Apocynum androsaemifolium*
Swamp milkweed *Asclepias incarnata*
Whorled wood aster *Aster acuminatus*
Bigleaf aster *Aster macrophyllus*
Parasol aster *Aster umbellatus*
White ash *Fraxinus americana*
Green ash *Fraxinus pennsylvanica*
Quaking aspen *Populus tremuloides*
Pin cherry *Prunus pennsylvanica*
Black cherry *Prunus serotina*
Common chokecherry *Prunus virginiana*
Staghorn sumac *Rhus typhina*
Allegheny blackberry *Rubus allegheniensis*
American elder *Sambucus canadensis*

Michigan

Seney

American basswood *Tilia americana*
Bigleaf aster *Aster macrophyllus*
Blackeyed Susan *Rudbeckia hirta*
Common milkweed *Asclepias syriaca*
Eastern poison ivy *Toxicodendron radicans*
Quaking aspen *Populus tremuloides*
Red maple *Acer rubrum*
Sambucus nigra *Sambucus canadensis*
Scarlet elderberry *Sambucus racemosa*
Spreading dogbane *Apocynum androsaemifolium*

Missouri
Mingo
Tuliptree *Liriodendendron tulipifera*
Virginia creeper *Parthenocissus quinquefolia*

Montana
Medicine Lake
Cheatgrass *Bromus tectorum*
Quaking aspen *Populus tremuloides*
White ash *Fraxinus americana*

New Jersey
Brigantine
Boxelder *Acer negundo*
Tree-of-heaven *Ailanthus altissima*
Common milkweed *Asclepias syriaca*
Cheatgrass *Bromus tectorum*
Sweet gum *Liquidambar styraciflua*
Virginia creeper *Parthenocissus quinquefolia*
Pitch pine *Pinus rigida*
Black cherry *Prunus serotina*
Winged sumac *Rhus copallina*
American elder *Sambucus canadensis*
Sassafras *Sassafras albidum*
Common lilac *Syringa vulgaris*
Poison-ivy *Toxicodendron radicans*
Grape *Vitis spp*.

North Dakota
Lostwood
Boxelder *Acer negundo*
Quaking aspen *Populus tremuloides*
Raspberry *Rubus idaeus*
Saskatoon serviceberry *Amelanchier alnifolia*

Oklahoma
Wichita Mountains
Blackeyed Susan *Rudbeckia hirta*
Cheatgrass *Bromus tectorum*
Eastern redbud *Cercis canadensis*
Green ash *Fraxinus pennsylvanica*
Smooth sumac *Rhus glabra*
Sugar Maple *Acer saccharum*
Virginia creeper *Parthenocissus quinquefolia*

South Carolina
Cape Romain
Sweetgum *Liquidambar styraciflua*
Virginia creeper *Parthenocissus quinquefolia*
Winged sumac *Rhus copallina*
American elder *Sambucus canadensis*
Chinese tallow tree *Sapium sabiferum*
Poison-ivy *Toxicodendron radicans*
Labrusca grape *Vitis labrusca*

Appendix 3.B. List of Representative Low and High W126 and N100 Values for SELECTED NPS and FWS Areas.

SITE = **ACADIA NATIONAL PARK**
AIRS SITE NUMBER = 23-009-0101

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
ACAD	1988	43925	89	4485	5136	87.3
ACAD	1996	10052	4	5085	5136	99.0

SITE = **ARCHES NATIONAL PARK**
AIRS SITE NUMBER = 49-019-0101

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
ARCH	1989	21199	0	4260	5136	82.9
ARCH	1990	1713	0	4639	5136	90.3

SITE = **BADLANDS NATIONAL PARK**
AIRS SITE NUMBER = 46-071-1001

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
BADL	1988	13332	0	4791	5136	93.3
BADL	1990	4766	0	4783	5136	93.1

SITE = **BANDELIER NATIONAL MONUMENT**
AIRS SITE NUMBER = 35-028-1002

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
BAND	1991	44945	0	4997	5136	97.3
BAND	1993	21854	0	4566	5136	88.9

SITE = **BIG BEND NATIONAL PARK**
AIRS SITE NUMBER = 48-043-0101

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
BIBE	1992	12169	0	4366	5136	85.0
BIBE	1994	26667	0	4702	5136	91.5

SITE = **BIG THICKET NATIONAL PRESERVE**
AIRS SITE NUMBER = 48-457-0101

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
BITH	1987	21554	16	4401	5136	85.7
BITH	1991	6763	1	3383	5136	65.9

SITE = **BRIGANTINE WILDERNESS AREA**
AIRS SITE NUMBER = 34-001-0005

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
BRIG	1991	67729	109	4963	5136	96.6
BRIG	1994	24901	2	4980	5136	97.0

SITE = **CANYONLANDS NATIONAL PARK**
AIRS SITE NUMBER = 49-037-0101

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
CANY	1993	21278	0	4390	5136	85.5
CANY	1996	49676	0	4373	5136	85.1

SITE = **CAPE COD NATIONAL SEASHORE**
AIRS SITE NUMBER = 25-001-0002

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
CACO	1988	70427	174	4856	5136	94.5
CACO	1993	23439	10	4675	5136	91.0

SITE = **CAPE ROMAIN WILDERNESS AREA**
AIRS SITE NUMBER = 45-019-0046

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
CARO	1991	4377	0	4943	5136	96.2
CARO	1993	19019	0	4945	5136	96.3

SITE = **CHAMIZAL NATIONAL MEMORIAL**
AIRS SITE NUMBER = 48-141-0044

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
CHAM	1993	5310	1	4549	5136	88.6
CHAM	1995	19564	14	4890	5136	95.2

SITE = **CHANNEL ISLANDS NATIONAL PARK**
AIRS SITE NUMBER = 06-111-0006

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
CHIS	1991	14943	0	3268	5136	63.6
CHIS	1992	33809	6	4549	5136	88.6

SITE = **CHIRICAHUA NATIONAL MONUMENT**
AIRS SITE NUMBER = 04-003-8001

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
CHIR	1992	20023	0	4521	5136	88.0
CHIR	1994	36119	0	5005	5136	97.4

SITE = **COLORADO NATIONAL MONUMENT**
AIRS SITE NUMBER = 08-077-0600

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
COLM	1987	35812	0	4418	5136	86.0
COLM	1990	12229	0	5012	5136	97.6

SITE = **CONGAREE SWAMP NATIONAL MONUMENT**
AIRS SITE NUMBER = 45-079-1006

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
COSW	1990	25577	14	4004	5136	78.0
COSW	1994	5329	0	4221	5136	82.2

SITE = **COWPENS NATIONAL BATTLEFIELD**
AIRS SITE NUMBER = 45-021-0002

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
COWP	1988	58732	69	4135	5136	80.5
COWP	1990	22474	0	4784	5136	93.1

SITE = **CRATERS OF THE MOON NATIONAL MONUMENT**
AIRS SITE NUMBER = 16-023-0101

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
CRMO	1993	8563	0	4506	5136	87.7
CRMO	1994	25462	0	4752	5136	92.5

SITE = **CUYAHOGA VALLEY NATIONAL RECREATION AREA**
AIRS SITE NUMBER = 39-153-2004

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
CUVA	1990	15249	15	3267	5136	63.6
CUVA	1991	39670	33	4193	5136	81.6

SITE = **DEATH VALLEY NATIONAL PARK**
AIRS SITE NUMBER = 06-027-0101

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
DEVA	1994	68630	1	4125	5136	80.3
DEVA	1996	46223	0	4380	5136	85.3

SITE = **DENALI NATIONAL PARK**
AIRS SITE NUMBER = 02-290-0003

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
DENA	1993	2590	0	4773	5136	92.9
DENA	1996	4144	0	4831	5136	94.1

SITE = EVERGLADES NATIONAL PARK
AIRS SITE NUMBER = 12-025-0030

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
EVER	1987	7968	0	3693	5136	71.9
EVER	1991	1568	0	4202	5136	81.8

SITE = **GLACIER NATIONAL PARK**
AIRS SITE NUMBER = 30-029-8001

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
GLAC	1989	5871	0	5136	5136	100.0
GLAC	1993	2314	0	5136	5136	100.0

SITE = **GREAT BASIN NATIONAL PARK**
AIRS SITE NUMBER = 32-033-0101

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
GRBA	1995	22881	0	4836	5136	94.2
GRBA	1996	38342	0	4800	5136	93.5

SITE = **GRAND CANYON NATIONAL PARK**
AIRS SITE NUMBER = 04-005-2003 AND 04-005-8001

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
GRCA	1990	15430	0	3827	5136	74.5
GRCA	1996	47476	0	4633	5136	90.2

SITE = **GREAT SAND DUNES NATIONAL MONUMENT**
AIRS SITE NUMBER = 08-003-0002

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
GRSA	1989	10777	0	4436	5136	86.4
GRSA	1991	16966	0	4130	5136	80.4

SITE = **GREAT SMOKY MTS NATIONAL PARK - CADES COVE SITE**
AIRS SITE NUMBER = 47-009-0102

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
GSCC	1994	14879	5	3988	5136	77.6
GSCC	1996	24268	0	4805	5136	93.6

SITE = **GREAT SMOKY MTS NATIONAL PARK - CLINGMANS DOME SITE**
AIRS SITE NUMBER = 47-155-0102

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
GSCD	1993	40757	0	4087	5136	79.6
GSCD	1996	74162	3	4104	5136	79.9

SITE = **GREAT SMOKY MTS NATIONAL PARK - COVE MT SITE**
AIRS SITE NUMBER = 47-155-0101

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
GSCM	1992	49135	3	4620	5136	90.0
GSCM	1996	98657	8	4879	5136	95.0

SITE = **GREAT SMOKY MTS NATIONAL PARK - LOOK ROCK SITE**
AIRS SITE NUMBER = 47-009-0101

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
GSLR	1991	36430	0	4504	5136	87.7
GSLR	1996	76608	5	4650	5136	90.5

SITE = **GUADALUPE MOUNTAINS NATIONAL PARK**
AIRS SITE NUMBER = 48-109-0101

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
GUMO	1990	13795	0	4531	5136	88.2
GUMO	1992	25368	0	4120	5136	80.2

SITE = **HALEAKALA NATIONAL PARK**
AIRS SITE NUMBER = 15-009-0101

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
HALE	1992	609	0	4842	5136	94.3
HALE	1993	1197	0	4668	5136	90.9

SITE = **HAWAII VOLCANOES NATIONAL PARK**
AIRS SITE NUMBER = 15-001-0005

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
HAVO	1987	3176	0	4068	5136	79.2
HAVO	1991	244	0	4775	5136	93.0

SITE = **INDIANA DUNES NATIONAL LAKESHORE**
AIRS SITE NUMBER = 18-127-0020

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
INDU	1989	11619	0	3708	5136	72.2
INDU	1990	64667	66	3944	5136	76.8

SITE = **ISLE ROYALE NATIONAL PARK**
AIRS SITE NUMBER = 26-061-0101

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
ISRO	1988	11169	0	2341	5136	45.6
ISRO	1991	6804	0	2631	5136	51.2

SITE = **JOSHUA TREE NATIONAL PARK**
AIRS SITE NUMBER = 06-065-9002 AND 06-071-9002

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
JOTR	1990	57422	32	3310	5136	64.4
JOTR	1994	151025	224	4839	5136	94.2

SITE = LASSEN VOLCANIC NATIONAL PARK
AIRS SITE NUMBER = 06-089-3003

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
LAVO	1993	11637	0	4586	5136	89.3
LAVO	1994	38104	0	4845	5136	94.3

SITE = **MAMMOTH CAVE NATIONAL PARK**
AIRS SITE NUMBER = 21-061-0500

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
MACA	1988	51761	74	4828	5136	94.0
MACA	1993	15306	1	4494	5136	87.5

SITE = **MESA VERDE NATIONAL PARK**
AIRS SITE NUMBER = 08-083-0101

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
MEVE	1994	20007	0	4832	5136	94.1
MEVE	1996	29698	0	4860	5136	94.6

SITE = **MOUNT RAINIER NATIONAL PARK**
AIRS SITE NUMBER = 53-053-1010

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
MORA	1993	2845	0	4565	5136	88.9
MORA	1994	6900	1	4224	5136	82.2

SITE = **NORTH CASCADES NATIONAL PARK**
AIRS SITE NUMBER = 53-057-0013

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
NOCA	1996	2173	0	4198	5136	81.7

SITE = **OLYMPIC NATIONAL PARK**
AIRS SITE NUMBER = 53-009-0012

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
OLYM	1993	712	0	4585	5136	89.3
OLYM	1995	1858	0	4667	5136	90.9

SITE = **PETRIFIED FOREST NATIONAL PARK**
AIRS SITE NUMBER = 04-001-0012

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
PEFO	1988	14446	1	4830	5136	94.0
PEFO	1989	25791	1	4696	5136	91.4

SITE = **PINNACLES NATIONAL MONUMENT**
AIRS SITE NUMBER = 06-069-0003

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
PINN	1987	78874	86	4737	5136	92.2
PINN	1994	32951	0	4771	5136	92.9

SITE = **POINT REYES NATIONAL SEASHORE**
AIRS SITE NUMBER = 06-041-0002

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
PORE	1989	4813	0	4577	5136	89.1
PORE	1990	1784	0	4856	5136	94.5

SITE = **REDWOOD NATIONAL PARK**
AIRS SITE NUMBER = 06-015-0002

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
REDW	1988	1814	0	4825	5136	93.9
REDW	1989	1015	0	4624	5136	90.0

SITE = **ROCKY MOUNTAIN NATIONAL PARK**
AIRS SITE NUMBER = 08-069-0007

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
ROMO	1990	5592	0	4091	5136	79.7
ROMO	1996	37033	0	4810	5136	93.7

SITE = **SAGUARO NATIONAL PARK**
AIRS SITE NUMBER = 04-019-0021

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
SAGU	1987	9184	0	3970	5136	77.3
SAGU	1993	46792	1	4761	5136	92.7

SITE = **SANTA MONICA MTNS NATIONAL RECREATION AREA**
AIRS SITE NUMBER = 06-037-1902

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
SAMO	1989	73919	238	4770	5136	92.9
SAMO	1991	63864	145	4700	5136	91.5

SITE = **SEQUOIA/KINGS CANYON NATIONAL PARKS - ASH MOUNTAIN**
AIRS SITE NUMBER = 06-107-0005

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
SEAM	1987	165538	245	4786	5136	93.2
SEAM	1995	97343	73	4812	5136	93.7

SITE = **SEQUOIA/KINGS CANYON NATIONAL PARKS - GRANT GROVE**
AIRS SITE NUMBER = 06-107-0007

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
SEGG	1994	135176	163	4814	5136	93.7
SEGG	1995	80484	32	4264	5136	83.0

SITE = **SEQUOIA/KINGS CANYON NATIONAL PARKS - LOWER KAWEAH**
AIRS SITE NUMBER = 06-107-0006

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
SELK	1993	130157	137	4847	5136	94.4
SELK	1995	71759	34	4786	5136	93.2

SITE = **SHENANDOAH NATIONAL PARK - BIG MEADOWS**
AIRS SITE NUMBER = 51-113-0003

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
SVBM	1988	81013	63	4448	5136	86.6
SVBM	1989	29297	0	4499	5136	87.6

SITE = **SHENANDOAH NATIONAL PARK - DICKEY RIDGE**
AIRS SITE NUMBER = 51-187-0002

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
SVDR	1988	99239	160	3784	5136	73.7
SVDR	1992	26841	0	4351	5136	84.7

SITE = **SHENANDOAH NATIONAL PARK - SAWMILL RUN**
AIRS SITE NUMBER = 51-015-0042

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
SVSR	1988	56538	47	4722	5136	91.9
SVSR	1989	16943	0	4490	5136	87.4

SITE = **THEODORE ROOSEVELT NATIONAL PARK - NORTH UNIT**
AIRS SITE NUMBER = 38-053-0002

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
TRNO	1989	14184	0	4206	5136	81.9
TRNO	1993	4573	0	4281	5136	83.4

SITE = **VOYAGEURS NATIONAL PARK**
AIRS SITE NUMBER = 27-071-0101 AND 27-137-0034

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
VOYA	1988	10026	3	4643	5136	90.4
VOYA						

SITE = **YOSEMITE NATIONAL PARK - WAWONA VALLEY**
AIRS SITE NUMBER = 06-043-0004

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
YOWV	1987	70513	44	4742	5136	92.3
YOWV	1994	27911	0	4720	5136	91.9

SITE = **YOSEMITE NATIONAL PARK - YOSEMITE VALLEY**
AIRS SITE NUMBER = 06-043-0005

PARK	YEAR	APR-OCT CUMULATIVE W126 EXPOSURE PPB-HRS	APR-OCT NO. OF HOURS WITH OZONE >=100PPB	APR-OCT NO. OF VALID HOURS OF OZONE	TOTAL NO. OF HOURS IN APR-OCT	PERCENT DATA CAPTURE FOR APR-OCT
YOYV	1991	15175	0	4620	5136	90.0
YOYV	1994	31740	1	4780	5136	93.1

4. DEPOSITION

a. Introduction

Atmospheric deposition has been studied extensively throughout the world, beginning in the 1800's in England, Sweden, Norway, and Germany. Research has primarily focused on the deposition of acidic pollutants and long-term acidification. Many publications describe current conditions, monitoring and modeling methods, and the results of acidification experiments. In the United States, research on acidification was first begun in 1962 at Hubbard Brook, New Hampshire. Subsequent work in the Adirondack lakes and other areas furthered the understanding of acid deposition effects. It is now recognized that, in addition to causing acidification, deposition of pollutants can affect many ecosystem characteristics, including nutrient cycling and biological diversity.

Although much progress has been made to control sulfur dioxide and nitrogen oxide emissions, deposition of sulfur (S) and nitrogen (N) compounds continues to be a problem in North America and Europe (Hedin and Likens 1996). As a result, certain sensitive freshwater lakes and streams continue to lose acid-neutralizing capacity (ANC) and sensitive soils continue to be acidified. Other ecosystems, including forests, grasslands, estuaries, and N-limited lakes exhibit unwanted fertilization and other effects from excess N deposition.

Federal Land Managers (FLMs) have documented the effects of S and N deposition on many air quality related values (AQRVs). Documented effects include acidification of lakes, streams, and soils; leaching of nutrients from soils; injury to high-elevation spruce forests; changes in terrestrial and aquatic species composition and abundance; changes in nutrient cycling; unnatural fertilization of terrestrial ecosystems; and eutrophication of estuarine and some lake systems. FLMs recognize that other undocumented effects may also be occurring.

The FLAG deposition subgroup was formed to identify common approaches among these agencies for evaluating atmospheric deposition and its effects on AQRVs. In addition, the subgroup was directed to recommend methods for establishing critical deposition loading values ("critical loads") and, where possible, recommend such critical loads for specific areas. These tasks were assigned to Phase I or Phase II, depending on their degree of difficulty.

During the scoping process, the FLAG Deposition Subgroup determined that Phase I tasks would include the summarization of information currently available about deposition and its effects on FLM areas and the development of recommendations on methods to model and evaluate current and future deposition and its effects on AQRVs. In addition, critical load values, where available from previous FLM guidance documents, would be referenced. FLMs agreed that site-specific AQRV and critical load information would be maintained on FLM web sites, rather than included in the Phase I report. In this way, the information can be updated and the most recent versions made quickly available to the public. Some of this information is already available on FLM web sites, and the FLMs are committed to entering remaining available information as soon as possible.

The subgroup recognizes that the development and refinement of site-specific critical load values for all FLM areas are crucial for AQRV protection. However, because of the complexity of this undertaking, and the lack of information for many areas, it was deferred to Phase II.

During Phase II, the subgroup will focus efforts on developing methods for establishing critical deposition loading values for FLM areas, and establishing critical loads for areas with adequate information. For areas lacking sufficient information to determine critical loads, strategies will be developed to obtain needed information. Previously established critical loads will be reviewed and refined as necessary. The subgroup will also explore alternative methods for estimating background deposition rates, including extrapolation techniques or modeling that considers the spatial scale of ecosystems and differences in elevation. Methods for addressing problems with dry deposition and cloud and fog deposition measurements will also be considered. In addition, Phase II will provide research or monitoring recommendations to improve our understanding of deposition and its effects, including effects on cultural resources.

b. Current Trends in Deposition

From 80%-99% of S emissions and from 83%-95% of nitrogen oxides emissions are anthropogenic (NAPAP 1991). As a result, most S and N deposition is anthropogenic in origin. The Clean Air Act mandated reductions in S and N emissions that should result in decreases in S and N deposition.

Deposition monitP oxram AP 1DP)ide

the sites, mostly in the West. Only one site had a significant decreasing trend. Given the increases in nitrate and ammonium, total N concentrations are clearly increasing at some locations.

Estimates of natural background S and N precipitation concentrations and deposition can be made from certain reliable early precipitation chemistry data (Junge 1958), precipitation data from carefully selected remote areas such as Alaska and Argentina, and to some extent from present NADP data from coastal Oregon and Alaska (NADP 1982-1997). Except for coastal Oregon, present precipitation S and N concentrations throughout the contiguous states exceed these estimates of natural background levels, primarily due to anthropogenic emissions of S and N compounds.

In this chapter, it is assumed that S is deposited into the environment primarily as sulfate ion and N is deposited primarily as nitrate and ammonium ions. Other ionic forms of S and N occur in the atmosphere, but information on their deposition into ecosystems is limited. For example, organic N may be important in some areas, but reliable measurement methods for organic N in atmospheric deposition are not widely available.

Figure D-2. Trends in sulfate ion concentration, 1983-1994 (Lynch *et al.* 1996).

Figure D-3. Trends in nitrate ion concentration, 1983-1994 (Lynch *et al*. 1996).

Figure D-4. Trends in ammonium ion concentration, 1983-1994 (Lynch *et al.* 1996).

c. Identification and Assessment of AQRVs

AQRVs sensitive to pollutant deposition have been identified in various documents published by the USDA/FS, NPS, and FWS, which are listed in the "General References" of Appendix H of this report. The FLMs have previously used a combination of approaches to identify AQRVs, including national and regional workshops, regional reviews, and site-specific studies. AQRV identification was based on information from peer-reviewed scientific literature and expert judgment. Because information on AQRVs may change as new data becomes available, the FLMs agree that AQRV information will be made available on FLM web sites to allow for updating and improve accessibility, as discussed in the Introduction to this chapter.

Information on AQRVs for many USDA/FS Class I areas can be found at

http://www.fs.fed.us/r6/aq/natarm.

The USDA/FS is currently adding to and updating this information.

NPS and FWS are currently developing a web site with AQRV information that will be linked to the NPS AirWeb at

http://www.nature.nps.gov/ard

and to the FWS National Wildlife Refuge System web site at

http://refuges.fws.gov.

FLMs recommend that permit applicants consult with the appropriate FLM (Appendix F) to determine the need for an AQRV analysis and, if applicable, the methods for the analysis.

All FLMs use a similar conceptual approach to identify AQRVs that reflects the FLMs' interest in maintaining the integrity of ecosystem structure and function and protecting the most sensitive ecosystem components. AQRVs can be categorized by the type of ecosystem in which they are found, such as terrestrial, freshwater, and estuarine ecosystems. Each ecosystem and its AQRVs responds somewhat differently to deposition and approaches to evaluating deposition effects must therefore be developed accordingly. In terrestrial ecosystems, detection of changes in production, decomposition, and nutrient cycling processes provide information on deposition stress. In aquatic and estuarine ecosystems, detection of changes in water chemistry and aquatic community composition and structure provide similar information. Table D-1 summarizes AQRV indicators that may be used to assess effects in various ecosystems.

Table D-1. Indicators for monitoring and evaluating effects from deposition of S and N.

ECOSYSTEM	INDICATORS FOR SULFUR DEPOSITION
Freshwater	Chemical change (ANC depression), changes in phytoplankton and benthic community composition, species diversity, biomass
Terrestrial	Leaching of soil cations, soil acidification, mobilization of aluminum ions
Estuarine	Saltwater not sensitive to S deposition; leaching of nutrients may occur in sandy nearshore soils
ECOSYSTEM	INDICATORS FOR NITROGEN DEPOSITION
Freshwater	Chemical change (ANC depression), changes in phytoplankton and benthic community composition, species diversity, biomass
Terrestrial	Changes in: litter and soil carbon and N dynamics; biomass; soil N processes; litter decomposition rates; soil microbe functional groups; soil organic matter quality and quantity; soilwater chemistry
Estuarine	Changes in: phytoplankton species composition and biomass; aquatic invertebrates; seagrass health and distribution; nutrient ratios; dissolved oxygen; trophic status

Terrestrial, freshwater, and estuarine AQRVs are discussed below. In addition, methods to evaluate S- and N-induced deposition stress are discussed.

Terrestrial Ecosystems

Terrestrial ecosystem AQRVs include flora, fauna, and soils. FLMs have identified, where possible, AQRVs, or characteristics of AQRVs, most likely to be sensitive to S and N deposition ("sensitive receptors"). For example, high-elevation spruce forests may be sensitive receptors. FLMs assess the condition of these sensitive receptors by evaluating some aspect of the receptor (the "sensitive receptor indicator", or "indicator"). For example, an indicator for high-elevation red spruce forests is the occurrence and extent of winter foliar injury. In general, the FLM has focused on deposition effects to vegetation and chemical receptors in terrestrial ecosystems, with little emphasis on fauna. In addition, there is increasing awareness among FLMs that certain soil fauna (*e.g.*, microorganisms and invertebrates) are very sensitive to deposition and can be used as sensitive receptors.

In terrestrial ecosystems, sulfate production is regulated primarily by chemical processes (Johnson *et al.* 1983) and it is rarely a limiting nutrient. Soil response to acidic deposition can be evaluated by monitoring the leaching of essential soil cations, soil acidification, and mobilization of ionic aluminum. These processes have been studied both in field and laboratory experiments, and are defined in detail in the literature (Mollitor and Raynal 1983, Richter *et al.* 1983, Johnson *et al.* 1983, Reuss and Johnson 1986). Effects of S deposition can be detected by monitoring calcium and magnesium ions and S in the litter layer and surface soils; calcium, magnesium, potassium, and sulfate ions in soil solution; cation exchange capacity (CEC); and base saturation.

In general, biological AQRVs do not provide reliable indicators of S deposition in terrestrial ecosystems except under extreme S deposition. Lichens have been used in some areas as biomonitors to demonstrate spatial trends in S deposition, particularly in areas with pronounced S deposition gradients. For example, isotopic analysis of lichens from Mt. Zirkel Wilderness, Colorado, indicated that power plants in the nearby Yampa Valley were the source of elevated S in the lichens (Jackson *et al.* 1996).

Unlike S, the production and mobility of N in ecosystems is regulated almost entirely by biological processes. N is a limiting nutrient in most terrestrial and estuarine ecosystems, and is seasonally limiting in many freshwater ecosystems. Most ecosystems can retain and process significant additions of N, with resulting increases in production and changes in species diversity, biomass, and nutrient cycling. However, these changes are usually considered to be undesirable in natural ecosystems. The ability to retain and process N varies significantly depending on watershed successional status, site and fire history, soil conditions, vegetation, and other non-human factors. When N inputs exceed an ecosystem's assimilation capacity, N is lost or leached, usually as nitrate, from the soil and can be detected in adjacent streams or lakes. This may occur following a major disturbance such as fire, logging, land use change, grazing, agriculture, or where atmospheric N deposition or experimental inputs exceed what the ecosystem can assimilate (Fenn and Dunn 1989, Fenn 1991, Fenn *et al.* 1996, Adams *et al.* 1997).

Studies in northern Europe (Dise and Wright 1995) found that European forests leached detectable levels of nitrate at inputs of about 10-25 kilograms N per hectare per year (kg N $ha^{-1}yr^{-1}$). Tundra and high-elevation alpine sites may leach N at much lower levels of input. Mountain watersheds in the western U.S. show signs of N leakage at wet deposition levels of 3-5 kg N $ha^{-1}yr^{-1}$ (Eilers *et al.* 1994; Williams *et al.* 1996; Williams and Tonnessen, in review). However, even high elevation, poorly vegetated ecosystems with limited soil development can process more than 80% of the atmospheric N input before it reaches the aquatic system (Campbell *et al.* 1995, Kendall *et al.* 1995). Although nitrogen leaching has often been used as an indicator of excess N deposition, major changes occur in below- and aboveground biomass, species diversity, and nutrient cycling long before N input levels are sufficient to cause nitrate leaching (NAPAP 1993, Tilman *et al.* 1997, Vitousek *et al.* 1997). For example, with ambient deposition rates of 7-10 kg N $ha^{-1}yr^{-1}$, a Minnesota Long-Term Ecological Research (LTER) grassland study observed shifts from native, warm-season grasses to low diversity mixtures dominated by cool-season grasses and a greater than 50% decline in species richness (Wedin and Tilman 1996, Tilman *et al.* 1997). Significant losses in terrestrial diversity may have already occurred over extensive areas of the U.S., particularly in forest understories, shrublands, grasslands, and in soil microbial communities.

Because significant ecological changes may occur before nitrate loss can be detected, more sensitive indicators than nitrate leaching are needed to evaluate N deposition effects. Such indicators include changes in carbon and N dynamics of litter and soil and biomass (Aber and Driscoll 1997, Magill *et al.* 1997). With knowledge of inputs and small-scale N fertilization studies, changes in soil organic matter quality and quantity in response to N deposition can be evaluated. Soil microbial communities control the quantity and quality of N available to ecosystems and may be very sensitive indicators of N deposition. Changes in soil microbe functional groups or biomass may provide good estimates of ecosystem critical loads and incremental effects. Soil N mineralization, small root growth, and carbon:nitrogen ratios of soil and microbial biomass are also sensitive to N deposition. Evidence suggests that current deposition rates may alter the production of dissolved organic carbon and organic N compounds in soils, which are important nutrient and energy sources for both terrestrial and aquatic ecosystems. These could also be used as indicators of N deposition effects. However, because there are many other variables that also affect soil processes, it may be very difficult to discern effects on any soil indicators that are solely attributable to N.

Freshwater Ecosystems

AQRVs in freshwater ecosystems include lakes and streams and their associated flora and fauna. Sensitive receptors include water chemistry and clarity, phytoplankton, zooplankton, fish, amphibians, macroinvertebrates, and benthic organisms. Water chemistry indicators that respond to deposition include pH, ANC, conductance, cations and anions, metals, and dissolved oxygen. Physical indicators, such as water clarity, and biological indicators, including species diversity, abundance, condition factor and productivity of fish, amphibians, macroinvertebrates, and plankton can also be used to detect deposition effects in aquatic ecosystems. Much research has been done on the sensitivity of aquatic species to deposition, many of which are discussed in the 1990 National Acid Precipitation Assessment Program (NAPAP) State of Science report (NAPAP 1991a) and the 1998 NAPAP report (NAPAP 1998).

Sulfur is not a limiting nutrient in freshwater ecosystems. However, there are small regions of the U.S., including some FLM areas, where a relatively high percentage of surface water is sensitive to present acidic inputs. In these areas, S deposition can cause decreases in ANC and pH. For these sensitive or low-ANC waters, the best approach to quantify S deposition effects is the procedure currently used, monitoring changes in ANC and pH.

Nitrogen deposition, like S deposition, can cause episodic acidification of surface water in certain sensitive high-elevation ecosystems that have low-ANC headwater lakes and streams. Episodic acidification occurs in these areas when deposition is as low as 3-5 kg N $ha^{-1}yr^{-1}$ (Williams *et al.* 1996).

Estuarine Ecosystems

AQRV sensitive receptors in estuarine ecosystems include plankton, seagrasses, and water chemistry and clarity. Associated coastal forest and dune soils may also be useful as sensitive receptors. Water and soil nutrient concentrations, phytoplankton species composition and abundance, seagrass health, and dissolved oxygen concentrations can be used to evaluate deposition effects.

In estuaries, S is not a limiting nutrient. In addition, estuarine waters are highly buffered and, therefore, not subject to acidification. However, many coastal forest and dune soils are dominated by sandy soils that are sensitive to leaching of limiting nutrients because of very low cation exchange capacity (Au 1974). Monitoring for change in estuarine areas with high S deposition should therefore focus on soil ion mobility. As soil calcium and magnesium levels are generally adequate because of deposition from marine sources, potassium is likely the only limiting nutrient subject to significant loss by sulfate leaching.

The role of N in estuaries is probably the best-documented example of anthropogenic alteration with a literature record dating back to the 1950s. Production and use of fertilizers, land use changes, and fossil fuel combustion have greatly increased the available N, normally a limiting nutrient, which enters coastal waters. This has increased estuarine production and accelerated the process of eutrophication. Eutrophication can result in dramatic algae blooms, anoxia, the production of toxic hydrogen sulfide gas, and species extirpation in estuarine ecosystems. Human induced eutrophication has been documented for many areas along the Atlantic and Gulf coasts, including the Chesapeake Bay, Tampa Bay, Sarasota Bay, Florida Bay, and Long Island Sound.

A number of FLM areas along the Atlantic and Gulf coasts contain significant coastal waters that may be sensitive to eutrophication. Little is known about excess N effects in most of these areas, although eutrophication is well documented in Florida Bay, located in Everglades National Park. Also, recent evidence indicates that coastal waters in Chassahowitzka Wilderness (Florida) experience N-induced algal blooms (Dixon and Estevez in draft). In most coastal waters, 10-45% of the N entering the system is atmospheric, either from direct deposition to surface water or deposition to the watershed. Complete elimination of atmospheric N inputs would not entirely mitigate ecosystem change due to N because of the substantial contributions from agricultural and urban runoff. However, for most estuaries, any reduction in N input would be beneficial in restoring ecosystem structure and function.

The monitoring procedures recommended, and currently used, in estuaries are similar to those used in freshwater, with emphasis on incremental changes in plankton, aquatic plant, benthic, and invertebrate community composition; species diversity, distribution, and biomass; and ecosystem trophic status.

Significance of Long-Term Monitoring to Evaluate Trends and Validate Modeling

Long-term monitoring is critical to evaluate trends in deposition and deposition effects. Monitoring programs should concentrate not only on areas with high past and/or present sulfate, nitrate, or ammonium deposition, but also in areas that are very sensitive to deposition and in areas where deposition is expected to increase. For selected monitoring sites, the FLM should (1) obtain ion deposition data for the site, as from NADP or CASTNet, (2) identify sensitive AQRVs and appropriate variables to monitor, (3) evaluate the present condition of the sensitive AQRVs, (4) determine the degree to which results from one site can be extrapolated to other FLM areas in the region, and lastly (5) implement a long-term monitoring program, using carefully selected variables.

Long-term monitoring data are also needed to support and validate models used to predict deposition and deposition effects, including the effects of increases or decreases of S and N on ecosystems. Long term studies in both aquatic and terrestrial ecosystems such as Hubbard Brook, Lake Tahoe, and the Experimental Lakes Area have provided useful information for modeling (Bormann and Likens 1967, Holm-Hanson *et al.* 1976, Likens and Bormann 1977, Leonard *et al.* 1979, Byron and Eloranta 1984, Schindler *et al.* 1985, Schindler 1987, Schindler *et al.* 1990, Jassby *et al.* 1995). NAPAP and the National Science Foundation LTER program have addressed monitoring to meet modeling needs in both terrestrial and aquatic ecosystems.

Data requirements to support models vary, but the quality of input data will determine the quality of a model's predictions. Modeling is further discussed in the "Other AQRV Identification and Assessment Tools" section of this chapter.

d. Determining Critical Loads

Critical load is defined by FLMs as "the concentration of air pollution above which a specific deleterious effect may occur." Critical loads have been widely accepted in Europe and Canada as a basis for negotiating control strategies for transboundary air pollution (Posch *et al.* 1997).

In Canada, researchers have estimated the critical loads of S in wet deposition necessary to protect moderately sensitive lakes in eastern provinces. That value, equivalent to 6.7 kg $ha^{-1}yr^{-1}$ of S in wet deposition, was used by Canada to argue for the U.S. to implement the Clean Air Act Amendments of 1990, which call for the initial reduction of sulfur dioxide emissions in the eastern U.S. and later from all electric utilities nationwide. With additional data on lake and stream chemistry available for sensitive systems in Nova Scotia, Ontario, and Quebec, the Canadians are now recommending a more stringent critical load, equivalent to 2.7 kg $ha^{-1}yr^{-1}$ of wet deposition S.

In both European countries and in North America, attention has expanded beyond ecosystem damage caused by S deposition to ecosystem damage caused by N deposition. In some European forests, chronically high N deposition has exceeded the assimilation capacity of local ecosystems, resulting in the release of nitrate into surface waters (Dise and Wright 1995). Watersheds that are leaking nitrate into surface waters during the growing season, are referred to as "N saturated" (Aber *et al.* 1989). Nitrogen saturation has been linked to forest decline in Europe (Schulze 1989). Based on a set of regional N addition experiments conducted at sites in northern Europe (NITREX), Wright (1995) recommended a N critical load of less than 10 kg $ha^{-1}yr^{-1}$ to protect European forests and freshwaters from N saturation. However, this critical load does not protect ecosystems from the changes caused by N deposition prior to actual N saturation, including shifts in composition and abundance of soil fauna species and alterations in soil chemistry.

In the United States, two states have attempted to set deposition standards or critical loads to protect sensitive ecosystems. In 1982, the State of Minnesota passed the Acid Deposition Control Act to limit wet sulfate deposition to 11 kg $ha^{-1}yr^{-1}$, which is equivalent to 3.7 kg S $ha^{-1}yr^{-1}$. At this sulfate level, precipitation pH was likely to remain above 4.7, which would protect lakes with ANC less than 50 microequivalents per liter (μeq l^{-1}). This critical load was to be achieved by controls on large sources of sulfur dioxide in Minnesota. As of 1990, monitoring by state officials showed no evidence of lake acidification under the sulfur dioxide control program. However, the efficacy of this control strategy is still uncertain, because as much as 90% of the sulfate deposited in northern Minnesota may have sources outside of the state (Orr *et al.* 1992).

In 1989, the California legislature adopted the Atmospheric Acidity Protection Act, which required the Air Resources Board (CARB) to "develop and adopt standards, to the extent supportable by scientific data, at levels which are necessary and appropriate to protect public health and sensitive ecosystems from adverse effects resulting from atmospheric acidity" (CARB 1993). An assessment of existing data identified the high elevation watersheds, surface waters, and mixed conifer forests of the Sierra Nevada and the Los Angeles Basin as sensitive ecosystems. CARB analyses suggested that appropriate standards would include a critical load value for inorganic N to protect forests, and critical loads for both N and S to protect poorly buffered lakes and streams. However, no acidity standards to protect human health or critical loads to protect ecosystems have been set in California to date.

The Clean Air Act Amendments of 1990, Title IV, section 404, called on the Environmental Protection Agency (EPA) to prepare a report on the feasibility and effectiveness of setting deposition standards nationwide to protect sensitive aquatic and terrestrial resources. The completed report includes a number of modeling analyses that project the effect of reductions in both S and N deposition in areas studied during NAPAP. EPA concluded that deposition standards could not be set at this time because of 1) the lack of clearly defined policy regarding appropriate or desired goals for protecting sensitive aquatic or terrestrial resources, and 2) key scientific uncertainties, particularly regarding nitrogen watershed processes. In addition, EPA recognized that a national deposition standard might be inappropriate because of differences among ecosystems. However, in response to public comments on the report, EPA stated that “Given an adequate level of monitoring and assessment data, Class I areas could serve as potential targets for standard setting activities.” (U.S. EPA 1995)

Critical Loads in FLM Areas

In the Clean Air Act, as amended in 1977, Congress gave FLMs an “affirmative responsibility” to protect AQRVs from the adverse effects of air pollution. Congress’ intent was, “…In cases of doubt the land manager should err on the side of protecting the air quality-related values for future generations…” (Senate Report No. 95-127, 95th Congress, 1st Session, 1977). In an effort to ensure AQRV protection, FLMs have established critical loads for many FLM areas. FLMs agree that a critical load should protect the most sensitive AQRVs within each FLM area and should be based on the best science available. As new scientific information becomes available, critical loads should be reviewed and updated. Critical loads should ensure that no unacceptable change occurs to the resource.

FLMs have previously used a combination of approaches to establish critical loads, including national and regional workshops, regional reviews, and site-specific studies (see Appendix H). In all cases, the FLMs have used peer-reviewed scientific literature and expert judgment to make their decisions. For example, the NPS has established critical loads for several national parks through regional reviews that have evaluated existing information on air quality, deposition, and effects on AQRVs in national parks. For these reviews, NPS grouped parks by region and ecosystem type, including the Pacific Northwest, the Colorado Plateau, and the Rocky Mountains, and conducted an empirical assessment of the status of aquatic and terrestrial resources. An analysis of deposition effects was done, using current deposition data for S and N and effects information from field observations and research. In the Pacific Northwest region, this analysis led researchers to recommend guidelines for critical loads of S and N to protect sensitive resources, particularly low-ANC lakes, streams and ponds. These guidelines for critical loads will be available on the NPS AirWeb site in the near future at:

http://www.nature.nps.gov/ard.

The FWS is also committed to establishing critical load guidelines to protect sensitive resources. These guidelines for critical loads will be available through the FWS National Wildlife Refuges site at:

http://refuges.fws.gov.

The USDA/FS has conducted a series of national and regional workshops to establish critical loads and concern thresholds. In the late 1980s, the USDA/FS published prototype methods for evaluating the effects of acid deposition on AQRVs, including *A Screening Procedure to Evaluate Air Pollution Effects on Class I Wilderness Areas* (Fox *et al.* 1989) and *Guidelines for Measuring the Physical, Chemical, and Biological Condition of Wilderness Ecosystems* (Fox *et al.* 1987). Subsequently, the USDA/FS held regional workshops to develop screening procedures for new air pollutant emissions sources. These workshops were comprised of national and regional USDA/FS land managers, deposition experts from the academic and air pollution research community, and agency air quality professionals. Dependent on the workshop leadership, each regional workshop followed a slightly different process and a variety of outputs and formats resulted. However, all workshops used a collaborative process to determine S and N deposition rates that would pose a risk to the aquatic and terrestrial ecosystems protected in FLM areas, while addressing the scientific uncertainty inherent in ecosystem response to acidic deposition. Critical load guidelines for many USDA/FS Class I areas are published in workshop reports (see Appendix H) and are available at:

http://www.fs.fed.us/r6/aq/natarm.

The USDA/FS is currently adding to and updating this information.

As resources permit, during Phase II of FLAG, the subgroup will develop methods for establishing critical deposition loading values for all FLM areas and recommend critical loads for areas where adequate information exists. For areas lacking sufficient information to determine critical loads, strategies will be developed to obtain needed information.

e. Other AQRV Identification and Assessment Tools

In addition to AQRV monitoring, there are several tools available to the FLM for identifying AQRVs and assessing the response of sensitive AQRVs to pollutant deposition. These include the aquatic effects expert system component of the FWS/NPS Air Synthesis, the Natural Resource Information System – Air Module (NRIS-Air), and deposition models such as the Model of Acidification of Groundwater in Catchments (MAGIC) and MAGIC-With Aggregated Nitrogen Dynamics (MAGIC-WAND).

Air Synthesis

Air Synthesis is an information management and decision-support computer system under development by NPS and FWS. Air Synthesis is designed to assist FLMs in determining potential effects of pollutants on AQRVs. It contains information on air quality and its effects in parks and wildernesses as well as natural resource data and annotated bibliographies of current literature on deposition. An interactive expert system module is under development for inclusion in Air Synthesis to allow FLMs to assess the current status of freshwaters and determine if these resources are likely to be affected by deposition of S or N. The aquatic effects expert system is being developed by regional scientists. This system will allow FLMs to input existing surface water data for lakes and streams to determine: (1) the acidification status of the waters, (2) the likely cause of high concentrations of acid anions (*e.g.,* deposition, land use, organic inputs) and, (3) the sensitivity of the waters to increases in N or S deposition. Results can be displayed in a geographic information system (GIS) image that color-codes the acidification status of lakes and streams. In addition, the expert system evaluates the completeness and the amount of uncertainty in water chemistry data sets. Air Synthesis will be available through the NPS AirWeb at:

http://www.nature.nps.gov/ard

or the FWS National Wildlife Refuge System web site at:

http://refuges.fws.gov.

Natural Resource Information System – Air Module (NRIS-Air)

The Air Module is part of the USDA/FS Natural Resource Information System that integrates various physical, biological and socioeconomic data within a system of database, map-based spatial information, and analytical tools. Version 1.0 of NRIS-Air, released in November 1998, tracks

AQRVs, sensitive receptors and indicators for each of the USDA/FS Class I areas. The water submodule provides data storage, reports, and tools for evaluating locally entered water quality and wet deposition data. It also integrates the NADP data set and the entire National Surface Water Survey including the Eastern and Western Lakes Surveys and the National Stream Survey. Future NRIS-Air versions under development will provide the information structure for visibility, flora, fauna, soil, geologic resources, cultural resources, and air quality data, as well as providing an air pollution permit tracking system.

Information from NRIS-Air, including USDA/FS Class I area AQRV information, is available at:

http://www.fs.fed.us/r6/aq/natarm.

Deposition Effects Models

A number of watershed process models have been developed and tested in an attempt to simulate the effects of S and N on soils, forests, and surface waters. These models are used by FLMs to predict effects from increases in deposition and vary from detailed, compartment models of watersheds to lumped parameter models that do not track different ions through each soil compartment. For a review of models developed under NAPAP see NAPAP 1991.

A commonly applied watershed model is MAGIC. MAGIC was first developed for eastern U.S. watersheds and then extensively tested and validated throughout Europe and North America (Cosby *et al.* 1985, 1995, 1996). The model was used by NAPAP in its 1990 Integrated Assessment to project surface water chemistry resulting from various deposition scenarios (NAPAP 1991b). In another application in the eastern U.S., MAGIC has been linked with a simple, empirical, dose/response fish model developed at University of Virginia, that makes it possible to predict changes in fish productivity based on modeled changes in streamwater chemistry.

As a result of NAPAP, there was increased awareness of the potential impacts of inorganic N deposition on watersheds and surface waters. In response, the MAGIC model was updated with a module called With Aggregated Nitrogen Dynamics (WAND). MAGIC-WAND is a process-based model that uses site-specific information on hydrology, soils, and hydrochemistry. The model predicts changes through time in lake or stream chemistry. These time-series of changes in pH and ANC can subsequently be used by FLMs to calculate critical S or N loads for watersheds.

MAGIC-WAND has been extensively tested in the Adirondacks and at watersheds in Maine. For example, the Bear Brook Watershed Manipulation Project uses MAGIC-WAND to predict the effects of experimentally added N and S on a test watershed. MAGIC-WAND has also been applied to watersheds in FLM areas in the Cascades, the Sierra Nevada, the Rocky Mountains, and the Wind River Range in an effort to quantify critical S and N loads to aquatic and terrestrial resources. In the southeastern U.S., MAGIC-WAND is being used under the auspices of the Southern Appalachian Mountains Initiative (SAMI) to predict the effects of future deposition scenarios on FLM areas. Future SAMI modeling efforts will link watershed model results with fish dose/response models. The ultimate goal is to calibrate MAGIC-WAND with landscape level data in order to set regional critical loads.

Other models are also in use. For example, the USDA/FS Rocky Mountain Region recommends using either CALPUFF or ISCST (or other approved models) to estimate S and N deposition. The *Screening Methodology for Calculating ANC Change to High Elevation Lakes* (USDA Forest Service

2000) summarizes procedures for estimating total deposition of S and N. The document also recommends computations for estimating alkalinity changes in lakes caused by increases in S and N deposition. Another model, the Nutrient Cycling Model (NuCM) has been used in the East to predict the effect of changes in deposition on nutrient concentrations in soils and vegetation.

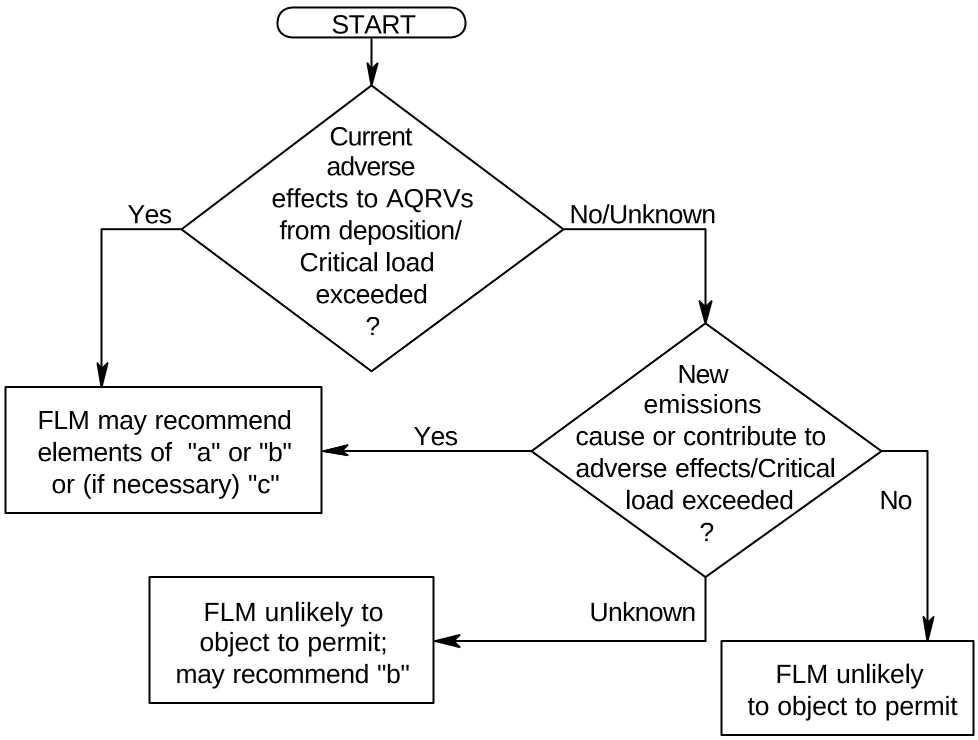
f. Recommendations and Guidance for Evaluating Potential Effects from Proposed Increases in Deposition to an FLM Area

FLMs often request that proponents of new emissions sources or modifications of existing sources near FLM areas provide sufficient information for the FLM to evaluate the potential effects of emissions increases on AQRVs. FLMs have provided guidance for applicants through guidance documents, correspondence, meetings, and phone consultations. This chapter summarizes current guidance for the evaluation of new emissions on deposition and sensitive AQRVs and includes recommendations for:

- the types of data, information, and analysis needed before a permit can be considered complete, including analytical and modeling protocols for a proponent's use in conducting an AQRV impact analysis;
- approaches and sources of appropriate values for estimating wet and dry deposition; and
- permit conditions to mitigate source impacts.

These recommendations can most easily be described using a flow chart. Figure D-1 summarizes the approaches to be taken to evaluate a proposed action.

Figure D-1. FLM response to potential deposition effects from new emissions sources.



a. The applicant should use one or more of the following:
  - Stricter (than BACT) controls (e.g., Lowest Achievable Emission Rate [LAER]).
  - Emission offsets located in an area that, considering geographic and meteorological factors, will benefit the impacted wilderness or park, as demostrated by modeling.
  - Regional modeling to identify sources contributing significantly to deposition adverse effects; SIP revision to reduce emissions contributing to adverse effects. (See text for discussion of mitigation options.)

b. Deposition and deposition effects monitoring/research in the FLM area.

c. Denial of permit.

The flowchart begins with the question, "Are there currently adverse effects from pollutant deposition to AQRVs in the FLM area?" To answer this question, the FLM needs information on deposition-sensitive AQRVs, deposition loads at which these AQRVs are affected (*i.e.,* critical loads), and the current pollutant deposition rates in the area. In areas where no information is available, information from a nearby, or ecologically similar area, may be used. An adverse effect may be expected to occur if the critical load is exceeded for an area. AQRV and critical load information are discussed earlier in this report. Procedures for estimating current pollutant deposition rates are summarized in the section, "Estimation of Current and Future Deposition Rates." After considering this information, the FLM determines if adverse effects to AQRVs already exist at an area. If adverse effects are present, the FLM may recommend that "a" or "b" or both of Figure D-1 are included as permit conditions. If these recommendations, or some combination of them, cannot be implemented, the FLM is likely to recommend denial of the permit.

If there are no current documented adverse effects from pollutant deposition to AQRVs, or there is a lack of information on deposition and deposition effects in the area (and information from nearby or ecologically similar areas is unavailable), the FLM may ask, "Will the proposed action cause an adverse effect to AQRVs?" The information needed to answer this question includes the information listed above regarding AQRVs, critical loads, and current deposition rates. In addition, an estimate is needed of the future predicted deposition rate. Procedures for this estimate are found in the "Estimation of Current and Future Deposition Rates" section of this report.

With this information, the FLM can determine if the proposed action is likely to cause an adverse effect to AQRVs. If the answer is no, or unknown, the FLM would not object to the action because of potential deposition effects. The FLM may still, however, object to the action for other reasons including an inadequate best available control technology analysis, predicted National Ambient Air Quality Standards violations, predicted Class I increment impacts, or other predicted AQRV impacts. If the available information is insufficient for the FLM to determine if the proposed action will cause an adverse effect to AQRVs, the FLM may ask for deposition and deposition effects monitoring and/or research in the FLM area (*i.e.,* item "b"). If the answer is yes and the proposed action will likely cause an adverse effect to AQRVs, the FLM may recommend permit conditions that ensure mitigation, including stricter emissions controls and effective emissions offsets (*i.e.,* item "a"). If no mitigation is possible, the FLM is likely to recommend denial of the permit.

<u>Available Deposition Monitoring Data</u>

Atmospheric pollutants are deposited to ecosystems primarily through wet deposition and dry deposition. FLMs participate in national monitoring programs to monitor wet and dry deposition, including the National Atmospheric Deposition Program (NADP) and the Clean Air Status and Trends Network (CASTNet). A 1999 report, "The Role of Monitoring Networks in the Management of the Nation's Air Quality," (CENR, 1999) identified these two networks as being critical for characterizing baseline air quality data in the U.S.

Wet Deposition

Wet deposition includes rain, snow, fog, cloudwater, and dew. In most FLM areas, rain and snow are the primary contributors to wet deposition. However, in some high elevation areas, fog, cloudwater, and dew are significant contributors, as discussed below.

Because rain and snow are the primary constituents of wet deposition at most FLM areas, the FLM generally relies on data from NADP to evaluate wet deposition of pollutants. NADP samplers collect rain and snow and NADP has documented deposition for many years in a nationwide network that currently includes over 220 monitoring sites. The network collects data to evaluate spatial and temporal long-term trends in precipitation chemistry. The precipitation at each site is collected weekly and sent to a central analytical laboratory for analysis of hydrogen (acidity as pH), sulfate, nitrate, ammonium, chloride, and base cations, including calcium, magnesium, potassium, and sodium. Data and isopleth maps of pollutant concentrations and deposition are available on the NADP web site at:

http://nadp.sws.uiuc.edu/

FLMs agree that it is preferable to obtain NADP data from the web site, rather than summarizing wet deposition data in this report. In this way, current data can be easily accessed by FLMs and the public.

Approximately 50 FLM areas have NADP samplers in or immediately adjacent to them. Because some of these areas are classified as wilderness, FLMs install sampling equipment in adjacent non-wilderness areas in order to preserve the wilderness character of the area. Ambient air in these adjacent areas is considered representative of air in the wilderness area.

A number of FLM areas do not have an NADP sampler in or adjacent to them. Where possible, the FLM has identified an NADP site whose data may be used to characterize deposition at the area. This information is appended to this Deposition chapter (Table D-2). Deposition rates generally increase with elevation and deposition in high-elevation areas may be difficult to characterize with data from a lower-elevation NADP site. FLM consultation may be necessary to estimate deposition in these areas.

Areas that experience significant deposition from fog and cloudwater or large amounts of snow may need to use alternate sampling methods and data in addition to NADP protocols and NADP data to characterize them. Wet deposition in these areas may need to be sampled with alternate methods, including cloudwater samplers and snowpack sampling or estimated by modeling. At sites where such data or modeled estimates are available, they should be used to calcu6ip, plWet depositing. e amoobtkly

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Dry Deposition

Dry deposition includes gases, aerosols and particles. The primary gases involved with N and S deposition are ammonia (NH_3), nitric oxide (NO), nitrogen dioxide (NO_2), nitric acid (HNO_3), and sulfur dioxide (SO_2), while the primary particles are nitrate (NO_3^-), ammonium (NH_4^+), and sulfate (SO_4^{2-}) ions (Hanson and Lindberg, 1991). Ammonia, NO, NO_2 and SO_2 are taken up by plants through stomata, while HNO_3, due to its high deposition velocity, is deposited to plant surfaces in addition to being taken up by stomata. Nitrate, ammonium, and sulfate particles deposit to surfaces (Bytnerowicz and Fenn, 1996).

Dry deposition is much more difficult to estimate than wet deposition. The estimation of dry deposition rates requires information on the ambient concentrations of pollutants, meteorological data, and information on land use, vegetation, and surface conditions, all of which are site-specific. Because of this site-specificity, it is difficult to spatially extrapolate dry deposition data as is often done for wet deposition data.

In general, FLMs rely on data from CASTNet for estimates of dry deposition in FLM areas (http://www.epa.gov/ardpublc/acidrain/castnet/index.html). CASTNet was developed by EPA, as a result of the Clean Air Act Amendments of 1990, and currently includes over 70 sites. These include a combination of former National Dry Deposition Network sites, Park Research and Intensive Monitoring of Ecosystems Network sites (PRIMENet), and others. Dry deposition is measured at 26 NPS areas and 2 USDA/FS areas. FLMs agree that it is preferable to obtain CASTNet data from the web site, rather than summarizing dry deposition data in this report. In this way, current data can be easily accessed by FLMs and the public.

Other methods for measuring dry deposition are available. For example, information on vertical changes in concentrations of major gases and particles of interest over plant canopies can be used for calculation of deposition of these compounds to forests and other ecosystems (Hicks *et al.*, 1987). Models, such as "Big-Leaf" (Baldocchi *et al.*, 1987) allow estimating dry deposition to uniform canopies, such as agricultural crops or lowland forests. However, no models have been developed so far for reliable estimates of deposition of gases and particles to forests and other ecosystems in complex mountain terrain (Bytnerowicz *et al.*, 1997). Therefore, no good large-scale estimates of dry deposition are available for western U.S. forests.

Another approach to evaluating dry deposition is net throughfall technique. By measuring concentrations of ions in throughfall (bulk precipitation) and after subtracting concentrations of the same ions in precipitation in an open area, fluxes of ions such as nitrate, ammonium, and sulfate can be calculated. A branch washing technique is similar to the net throughfall approach and is used when no wet precipitation is present. The pre-washed branches are exposed to ambient air for a certain time period and then carefully rinsed with water (Lindberg and Lovett, 1985). Information about amounts of nitrate, ammonium and sulfate rinsed from branches of a known surface area, time of exposure, and leaf area index of a given forest stand allow the calculation of fluxes of the measured ions to trees. Adding stomatal uptake of gases (calculated from information on gas concentration and stomatal conductance), and estimates of deposition to other landscape forms (such as soils and rocks) allow for quite reliable estimates of dry deposition at a forest stand level (Bytnerowicz *et al.*, 2000). Such estimates have been made for the subalpine zone of the eastern Sierra Nevada and mixed conifer forests on the western Sierra Nevada and the San Bernardino Mountains (Bytnerowicz and Fenn, 1996; Bytnerowicz *et al.*, 1999). Both the net throughfall and branch washing techniques, although providing relatively accurate estimates of deposition to certain ecosystems, cannot be applied to every type of vegetation. These techniques work well for conifers with relatively thick cuticles. For plants with thinner cuticle, extraction of ions from plant interior or transcuticular uptake of deposited ions may not allow for making good estimates of dry deposition to plant surfaces.

Recent developments, such as passive samplers that allow for relatively inexpensive determinations of nitric oxide, nitrogen dioxide, ammonia, nitric acid and sulfur dioxide concentrations, provide some promising opportunities for large-scale estimates of distribution of these pollutants. This, together with information on landscape-level vegetation coverage, leaf area index, and deposition velocity of the monitored pollutants, will allow calculating deposition of the measured gases to various landscape forms. Although this approach would not include deposition fluxes of particulate pollutants, a large portion of dry N and S deposition (gases) would be covered. Information on fluxes of the N and S particulate component (nitrate, ammonium, and sulfate ion concentrations) can be estimated based on their concentrations from annular denuder/filter pack systems or other comparable techniques and literature values of deposition velocities of these ions.

For many FLM areas, detailed site-specific information and monitoring needed for dry deposition measurements are not available. Therefore, the FLM may choose to recommend a reasonable estimate of dry deposition. NAPAP's 1991 summary report concluded that dry deposition of sulfur is 30-60% of the total (wet plus dry) deposition at regionally representative sites; dry deposition of nitrogen is 30-70% of the total (wet plus dry) deposition at regionally representative sites (NAPAP 1991a). An analysis of one year (1991) of NADP, CASTNet, and IMPROVE (Interagency Monitoring of Protected Visual Environments) data from national parks and wildernesses found that wet deposition dominated total deposition in both the East and the West. Dry deposition of sulfur was 20-50% of the total; dry deposition of nitrogen was 30-60% of the total (Hidy 1998). These estimates, and similar ones, have led to the common assumption that dry deposition is approximately 50% of the total deposition. Therefore, for many FLM areas without on-site or nearby representative dry deposition sampling, the FLM may recommend that dry deposition is equal to wet deposition. The FLM recommends this as a "best available estimate," recognizing that in some areas it may result in under- or over-estimating total deposition. Total deposition, which is the sum of wet plus dry deposition, therefore equals twice the wet deposition.

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Other Deposition Measurement Methods

Pollutant deposition, particularly in areas where traditional wet and dry deposition sampling is impractical, can also be estimated by other methods. These methods include bulk samplers that collect both wet and dry deposition and snowpack measurements that estimate the total amount of pollutants in the snow column at the time of maximum snow accumulation. Special methods have also been developed for collecting fog and cloud water (Anderson *et al.* 1999).

In addition, methods are being developed to estimate dry deposition rates from pollutant concentrations obtained by IMPROVE fine particle samplers. IMPROVE samplers are located at many FLM areas and expanded coverage is planned for 1999.

Modeling Deposition Rates

Deposition from existing sources can be estimated from deposition monitoring data, but contributions to deposition from the proposed source and other sources permitted but not yet operating must be modeled.

Modeling should be done in accordance with recommendations developed by the Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2:

http://www.epa.gov/scram001/t29.htm.

IWAQM provides the procedures that can be used to estimate S and N deposition from a proposed source and other sources permitted but not yet operating. The FLMs propose that these procedures be used to estimate S and N deposition. For S deposition, the wet and dry fluxes of sulfur dioxide and sulfate are calculated, normalized by the molecular weight of S, and expressed as total S. For N deposition, IWAQM recommends that the wet and dry fluxes of nitric acid (HNO_3) and nitrate (NO_3^-) and the dry flux of nitrogen oxides (NO_x) be calculated, normalized by the molecular weight of N, and expressed as total N. In addition, the FLMs agree that wet and dry fluxes of ammonium sulfate ($(NH_4)_2SO_4$)) and ammonium nitrate (NH_4NO_3) should be calculated, normalized by the molecular weight of N, and added to the estimate of total N. Therefore, total N deposition is the sum of N contributed by dry and wet fluxes of HNO_3, NO_3^-, $(NH_4)_2SO_4$, and NH_4NO_3 and the dry flux of NO_x.

The FLMs recognize that the ammonia (NH_3) in these compounds is derived from both man-made and natural sources. Free gaseous NH_3 has a high deposition velocity and tends to deposit quickly. However, if sulfates and nitrates (which are primarily man-made) are present in the atmosphere, free NH_3 quickly reacts to form $(NH_4)_2SO_4$ and NH_4NO_3. These compounds, because of their fine particle size and slower deposition velocity than free gaseous NH_3, can be transported long distances and deposited in a FLM area, adding to the total N deposition loading.

An appropriate estimate of ambient free gaseous NH_3 is needed for the modeling analysis. IWAQM refers to Langford *et al.* (1992), who suggest that typical (within a factor of 2) background values of NH_3 are: 10 parts per billion (ppb) for grasslands, 0.5 ppb for forest, and 1 ppb for arid lands at 20^{o}C. Langford *et al.* (1992) provide strong evidence that background levels of NH_3 show strong dependence with ambient temperature (variations of a factor of 3 or 4) and a strong dependence on the soil pH. However, given all the uncertainties in NH_3 data, IWAQM recommends use of the background levels provided above, unless better data are available for the specific modeling domain. IWAQM notes that in areas where there are high ambient levels of sulfate, values such as 10 ppb might overestimate the formation of particulate nitrate from a given source, for these polluted conditions. IWAQM further notes that areas in the vicinity of strong point sources of NH_3, such as feed lots or other agricultural areas, may experience locally high levels of background NH_3.

Questions regarding these recommendations should be resolved through consultation with the appropriate FLM and the appropriate State and/or EPA modeling representative. Applicants should provide a modeling protocol to the appropriate FLM prior to conducting modeling analyses.

Estimation of Current and Future Deposition Rates

In order to evaluate a proposed source's contribution to total (wet + dry) deposition in a FLM area, it is necessary to first estimate current pollutant deposition rates. The current rate is a result of deposition from all existing natural and anthropogenic sources. FLMs use two approaches to estimating the current rate of deposition. One approach estimates the current rate by averaging data from an appropriate monitoring site for the pollutant of interest, using all years with complete data records. The second, more conservative, approach assumes that the current rate is equivalent to the highest rate for the pollutant of interest in the data record.

The method for estimating future total deposition rates is:

1. Identify in table D-2 available on-site or representative wet and dry deposition data for the FLM area. Wet deposition data can be obtained through NADP (http://nadp.sws.uiuc.edu/).

   Dry deposition data can be obtained through CASTNet at (http://www.epa.gov/ardpublc/acidrain/castnet/index.html).

   Table D-2 will indicate if dry deposition is assumed to equal wet deposition for the site. For high-elevation sites, consult with the FLM to determine if deposition from cloudwater, fog, dew, or snowpack should be considered. For sites without on-site data, consult FLM for further guidance.

2. After consulting with the FLM, estimate either:
   a. the average annual or seasonal wet and dry deposition rates for the appropriate pollutant using all years with complete data records; or
   b. the highest annual or seasonal wet and dry deposition rates for the appropriate pollutant using all years with complete data records.

3. Calculate current total deposition (wet + dry = total).

4. Estimate, using the appropriate dispersion model as described in the "Modeling Deposition Rates" section above, the proposed source's contribution to future total deposition on an annual or seasonal basis.

5. Estimate, using appropriate dispersion model as described in the "Modeling Deposition Rates" section above, the contribution of any sources permitted but not yet operating to future total deposition. This estimate may be available from the State permitting authority.

6. The current pollutant deposition rate plus the proposed source's contribution to deposition plus the contribution from other sources permitted but not yet operating equals the future total deposition rate.

Current + Proposed + Permitted (not yet operating) = Future Total Deposition

This future total deposition rate for a given pollutant can then be used to determine the potential for adverse effects to AQRVs. If appropriate, the change in deposition rate can be used to estimate changes in pH or ANC in an ecosystem. If the future total deposition rate is expected to cause an adverse effect to AQRVs and/or exceeds the critical load established for a FLM area, the FLM may recommend mitigation, as outlined in the flowchart on Figure D-1. If no critical load has been established for the FLM area, the FLM will use the best information available in determining whether to recommend mitigation.

g. Summary

- Deposition of S and N has the potential to affect terrestrial, freshwater, and estuarine ecosystems on FLM lands.
- The FLM has identified, where possible, AQRVs sensitive to deposition of S and N on FLM lands and the critical loads associated with those AQRVs.
- A proponent of a source of new emissions with the potential to contribute to S or N deposition in an FLM area should consult with the FLM to determine what analyses are needed to assess AQRV effects. The FLM may request a deposition impact analysis, described in detail in this chapter and summarized below.

    1. Estimate the current deposition rate to the FLM area. A list of monitoring sites providing data to characterize deposition in FLM areas is included in Table D-2.
    2. Estimate the future deposition rate by adding the existing rate, the new emissions' contribution to deposition, and the contribution of sources permitted but not yet operating. Modeling of new and permitted but not yet operating emissions' contribution to deposition should be conducted following IWAQM Phase 2 recommendations.
    3. Compare the future deposition rate with the recommended screening criteria (*e.g.*, critical load, concern threshold, or screening level value) for the affected FLM area. A list of documents summarizing these screening criteria, where available, can be found in Appendix H. Information for USDA/FS Class I areas is also available at:

        http://www.fs.fed.us/r6/aq/natarm.

        A web site with NPS and FWS Class I area information is currently under development. The web site will be available at

        http://www.nature.nps.gov/ard and http://refuges.fws.gov.

        The appropriate FLM should be contacted for additional information.

h. Websites for Deposition and Related Information

Clean Air Status and Trends Network (CASTNet) dry deposition data:
http://www.epa.gov/ardpublc/acidrain/castnet/index.html

IWAQM guidance for deposition modeling: http://www.epa.gov/scram001/t29.htm.

National Acid Precipitation Assessment Program:
http://www.nnic.noaa.gov/CENR/NAPAP/NAPAP_96.htm

National Atmospheric Deposition Program (NADP) wet deposition data: http://nadp.sws.uiuc.edu/

National Park Service Airweb: http://www.nature.nps.gov/ard/

Natural Resources Conservation Service, Snow Water Equivalent Information (SNOTEL):
www.wcc.nrcs.usda.gov/factpub/sntlfct1.html

Southern Appalachian Man and the Biosphere Cooperative, Southern Appalachian Assessment:
http://sunsite.utk.edu/neighborhoods/SAMAB/samab/index.html

USDA Forest Service National Air Resource Management Web Site:
http://www.fs.fed.us/r6/aq/natarm

U.S. EPA Office of Air and Radiation:
http://www.epa.gov/oar

U.S. EPA, Deposition to Estuaries:
http://www.epa.gov/owow/oceans/airdep

U.S. EPA, STOrage and RETrieval System for Water and Biological Monitoring Data (STORET):
http://www.epa.gov/OWOW/STORET/

U.S. Fish and Wildlife Service Air Quality Branch: http://www.nature.nps.gov/ard/fws/fwsaqb.htm

U.S. Geological Survey, National Water-Quality Assessment (NAWQA) Program:
http://wwwrvares.er.usgs.gov/nawqa/nawqa_home.html

U.S. Geological Survey, Acid Rain Program:
http://bqs.usgs.gov/acidrain

U.S. Geological Survey, Water Data Storage and Retrieval System (WATSTORE):
http://h2o.er.usgs.gov/public/nawdex/wats/intro.html

Fact Sheet: http://water.usgs.gov/public/pubs/FS/FS-013-97/

Table D-2. Sites used for estimating wet and dry deposition in Class I Areas (distance and direction, when noted, refer to the location of the monitoring site relative to the Class I area).

	ESTIMATION OF WET DEPOSITION – NADP			ESTIMATION OF DRY DEPOSITION - CASTNet		
National Park Service Class I Units	On-site monitoring	Cal Code	Comments	On-site monitoring	Site/ID	Comments
Acadia NP	Y	ME98		Y	ACAD	
Arches NP	N	UT98		N		dry = wet
Badlands NP	N	SD08		N		dry = wet
Bandelier NM	Y	NM07		N		dry = wet
Big Bend NP	Y	TX04		Y	BIBE	
Black Canyon of the Gunnison NP	N	CO08		N		dry = wet
Bryce Canyon NP	Y	UT99		N		dry = wet
Canyonlands NP	Y	UT98		Y	CANY	
Capitol Reef NP	N	UT99		N		dry = wet
Carlsbad Caverns NP	N	TX22		N		dry = wet
Chiricahua NM	Y	AZ98		Y	CHIR	
Crater Lake NP	N	OR09		N		dry = wet
Craters of the Moon NM	Y	ID03		N		dry = wet
Denali NP	Y	AK03		Y	DENA	
Everglades NP	Y	FL11		Y	EVER	
Glacier NP	Y	MT05		Y	GLAC	
Grand Canyon NP	Y	AZ03		Y	GRCA	
Grand Teton NP	N	WY08		N		dry = wet
Great Sand Dunes NM	N	CO00		N		dry = wet
Great Smoky Mountains NP	Y	TN11		Y	GRSM	Use background value N dep=17.4 kg/ha/yr S dep=35.7 kg/ha/yr (includes wet+dry+cloud/fog) (SAMI)
Guadalupe Mountains NP	Y	TX22		N		dry = wet
Haleakala NP	N		N/A	N		dry = wet
Hawaii Volcanoes NP	Y	HI99		N		dry = wet
Isle Royale NP	Y	MI97		N		dry = wet
Joshua Tree NP	Y	CA67		Y	JOTR	
Lassen Volcanic NP	Y	CA96		Y	LAVO	
Lava Beds NM	N	CA76		N		dry = wet

	ESTIMATION OF WET DEPOSITION – NADP			ESTIMATION OF DRY DEPOSITION - CASTNet		
National Park Service Class I Units	On-site monitoring	Cal Code	Comments	On-site monitoring	Site/ID	Comments
Mammoth Cave NP	N	KY99		N		dry = wet
Mesa Verde NP	Y	CO99		Y	MEVE	
Mount Rainier NP	Y	WA99		Y	MORA	
North Cascades NP	Y	WA19		Y	NOCA	
Olympic NP	Y	WA14		Y	OLYM	
Petrified Forest NP	N	AZ03		N		dry = wet
Pinnacles NM	Y	CA66		Y	PINN	
Point Reyes NS	N		N/A	N		dry = wet
Redwood NP	N		N/A	N		dry = wet
Rocky Mountain NP	Y	CO98/19		Y	ROMO	
Saguaro NP	N	AZ99		N		dry = wet
Sequoia / Kings Canyon NPs	Y	CA75		Y	SEKI	
Shenandoah NP	Y	VA28		Y	SHEN	
Theodore Roosevelt NP	Y	ND07		Y	THRO	
Virgin Islands NP	Y	VI01		Y	VIIS	
Voyageurs NP	Y	MN23		Y	VOYA	
Wind Cave NP	N	SD08		N		dry = wet
Yellowstone NP	Y	WY08		Y	YELL	
Yosemite NP	Y	CA99		Y	YOSE	
Zion NP	N	UT99		N		dry = wet

	ESTIMATION OF WET DEPOSITION – NADP			ESTIMATION OF DRY DEPOSITION - CASTNet		
Forest Service Class I Areas	On-site monitoring	Cal Code	Comments	On-site monitoring	Site/ID	Comments
Agua Tibia	N		N/A	N		N/A
Alpine Lake	N	WA19/21	70 miles N/70 mi SW	N		dry = wet
Anaconda-Pintler	N	MT97	15 mi NE	N		dry = wet
Ansel Adams	N		N/A	N		N/A
Bob Marshall	N	MT05	65 mi NW	N	468 GNP	65 mi NW

	ESTIMATION OF WET DEPOSITION – NADP			ESTIMATION OF DRY DEPOSITION - CASTNet		
Forest Service Class I Areas	On-site monitoring	Cal Code	Comments	On-site monitoring	Site/ID	Comments
Boundary Waters	Y	MN18/08	adjacent	N		dry = wet
Bradwell Bay	N	FL14/*	30 mi N/ 17 mi SW	N	156 SUM	17 mi SW
Bridger	N	WY06/ WY98	6 mi SW/ 4 mi W	N	165 PND	6 mi W, bulk dep available
Cabinet Mountains	N	MT05	85 mi E	N		dry = wet
Caney Creek	N	AR03	60 mi SE	N	150 CAD	60 mi SE
Caribou	N		N/A	N		N/A
Chiricahua	N	AZ99	92 mi NW	Y	467 CNM/167 CNM	adjacent
Cohutta	N	TN11		N	GRSM	
Cucamonga	N		N/A	N		N/A
Desolation	N		N/A	N		N/A
Diamond Peak	N	OR10	45 mi N	N		dry = wet
Dolly Sods	N	WV18	17 mi W	N	107 PAR	17 mi W
Dome Land	N		N/A	N		N/A
Eagle Cap	N	OR18	35 mi W	N		dry = wet
Eagles Nest	N	CO02/94	40 mi NE	N		dry = wet
Emigrant	N		N/A	N		N/A
Fitzpatrick	N	WY06/ WY98	13 mi SW/ 17 mi W	N	165 PND	13 mi W, bulk dep available
Flat Tops	N	CO92/ CO08	25 mi SW	N		dry = wet
Galiuro	N	AZ99	40 mi N/NE	N	467 CNM/167 CNM	75 mi SE
Gates of the Mountains	N	MT05	30 mi S	N		dry = wet
Gearhart Mountain	N	OR9	45 mi N	N		dry = wet
Gila	Y	NM01	adjacent	N		dry = wet
Glacier Peak	N	WA19	10 mi NW	N		dry = wet

	ESTIMATION OF WET DEPOSITION – NADP			ESTIMATION OF DRY DEPOSITION - CASTNet		
Forest Service Class I Areas	On-site monitoring	Cal Code	Comments	On-site monitoring	Site/ID	Comments
Goat Rocks	N	WA21	40 mi NW	N		dry = wet
Great Gulf	N	NH02/ME02	30 mi SW/35 mi SE	N	109 WST	30 mi SW
Hells Canyon	N	OR18/ID04	90 mi W/85 mi NE	N		dry = wet
Hercules-Glades	N	AR16/27	50 mi SE/90 mi SW	N		dry = wet
Hoover	N		N/A	N		N/A
James River Face	N	VA13	65 mi W	N	120 VPI	65 mi W
Jarbidge	N		N/A	N	164 SAV	50 mi SW
John Muir	N		N/A	N		N/A
Joyce-Kilmer-Slickrock	N		N/A	N	137 COW	45 mi E
Kaiser	N		N/A	N		N/A
Kalmiopsis	N		N/A	N		dry = wet
La Garita	N	CO91	30 mi S	N		dry = wet
Linville Gorge	N		N/A	N	126 PNF	15 mi N
Lye Brook	Y	VT01/*	20 mi SW/adjacent	Y	145 LYE	adjacent
Marble Mountain	N		N/A	N		N/A
Maroon Bells-Snowmass	N	*	3 mi S	N	161 GTH	3 mi S
Mazatzal	N	AZ03	142 mi N/NW	N	474 GCN/174 GCN	142 mi N/NW
Mission Mountains	N	MT05	60 mi N	N		dry = wet
Mokelumne	N		N/A	N		N/A
Mount Adams	N	OR98	55 mi NE	N		
Mount Baldy	N	AZ99	67 mi SW	N		dry = wet
Mount Hood	N	OR98	20 mi NW	N		dry = wet
Mount Jefferson	N	OR10	30 mi SW	N		dry = wet
Mount Washington	N	OR10	15 mi SW	N		dry = wet

	ESTIMATION OF WET DEPOSITION – NADP			ESTIMATION OF DRY DEPOSITION - CASTNet		
Forest Service Class I Areas	On-site monitoring	Cal Code	Comments	On-site monitoring	Site/ID	Comments
Mountain Lakes	N	CA76/OR10	50 mi SW/125 mi N	N		dry = wet
North Absaroka	N	WY08	30 mi W	N		dry = wet
Otter Creek	N	WV18	4 mi N	N	107 PAR	4 mi N
Pasayten	N	WA19	30 mi SW	N		dry = wet
Pecos	N	NM07	38 mi SW	N	405 MEV	163 mi NW
Pine Mountain	N	AZ03	125 mi N	N	474 GCN/174 GCN	125 mi N
Presidential Range-Dry River	N	NH02/ME02	25 mi SW/30 mi SE	N	109 WST	25 mi SW
Rainbow Lake	N	WI37/36	45 mi SW/70 mi E	N	134 PRK	70 mi S
Rawah	N	CO98/19	25 mi SW	N	169 CNT/406 ROM	30 mi NW/20 mi SE
San Gabriel	N		N/A	N		N/A
San Gorgonio	N		N/A	N		N/A
San Jacinto	N		N/A	N		N/A
San Pedro Parks	N	NM09	4 mi SW	N	405 MEV	113 mi NW
San Rafael	N		N/A	N		N/A
Sawtooth	N	ID15/03	50 mi NW/80 mi SE	N		dry = wet
Scapegoat	N	MT05	100 mi NW	N		dry = wet
Selway-Bitterroot	N	MT97	20 mi SE	N		dry = wet
Shining Rock	N		N/A	N	137 COW	20 mi W
Sierra Ancha	N	AZ03	175 mi NW	N	474 GCN/174 GCN	175 mi NW
Sipsey	N		N/A	N		dry = wet
South Warner	N	AL99/10	80 mi E/140 mi S	N		N/A
Strawberry Mountain	N	OR18	75 mi N	N		dry = wet
Superstition	N	AZ06	142 mi NW	N		dry = wet

	ESTIMATION OF WET DEPOSITION – NADP			ESTIMATION OF DRY DEPOSITION - CASTNet		
Forest Service Class I Areas	On-site monitoring	Cal Code	Comments	On-site monitoring	Site/ID	Comments
Sycamore Canyon	N	AZ06	79 mi N	N	474 GCN/174 GCN	79 mi N
Teton	N	WY08/ WY98	NW/SE	N		dry = wet
Thousand Lakes	N		N/A	N		N/A
Three Sisters	N	OR10	5 mi NW	N		dry = wet
Upper Buffalo	N	AR16/27	60 mi NE/45 mi NW	N		dry = wet
Ventana	N		N/A	N		dry = wet
Washakie	N	WY08/98	45 mi NW/60 mi S	N		dry = wet
Weminuche	Y	CO96/91	6 mi NW/adjacent	N	405 MEV	45 mi SW
West Elk	N	*	20 mi NE	N	161 GTH	20 mi NE
Wheeler Peak	N	NM12	83 mi NE	N	405 MEV	130 mi NW
White Mountain	N	NM08	42 mi SE	N		dry = wet
Yolla Bolly Middle Eel	N		N/A	N		N/A

	ESTIMATION OF WET DEPOSITION – NADP			ESTIMATION OF DRY DEPOSITION - CASTNet		
Fish and Wildlife Class I Areas	On-site monitoring	Cal Code	Comments	On-site monitoring	Site/ID	Comments
Bering Sea	N	AK03	1100 km E	N		dry = wet
Bosque del Apache	N	NM08	163 km SE	N		dry = wet
Breton	N	LA30	175 km NW	N		dry = wet
Brigantine	Y	NJ00	on-site	N		dry = wet
Cape Romain	starts 9/2000	SC18	87 km NW; use on-site data when available	N		dry = wet
Chassahowitzka	Y	FL05	on-site	N		dry = wet
Lostwood	N	MT13	130 km SW	N		dry = wet

	ESTIMATION OF WET DEPOSITION – NADP			ESTIMATION OF DRY DEPOSITION - CASTNet		
Fish and Wildlife Class I Areas	On-site monitoring	Cal Code	Comments	On-site monitoring	Site/ID	Comments
Medicine Lake	N	MT13	47 km W	N		dry = wet
Mingo	N	MO05	1 km SW	N		dry = wet
Moosehorn	N	ME98	107 km SW	N		dry = wet
Okefenokee	Y	GA09	On-site	N		dry = wet
Red Rock Lakes	N	WY08	106 km NE	N		dry = wet
Salt Creek	N	NM08	120 km SW	N		dry = wet
Seney	starts 9/2000	MI98	98 km E; use on-site data when avail.	N		dry = wet
Simeonof	N	AK03	1200 km NE	N		dry = wet
St. Marks	N	FL23	50 km W	N		dry = wet
Swanquarter	N	NC06	80 km S	N		dry = wet
Tuxedni	N	AK03	450 km NE	N		dry = wet
UL Bend	N	MT98	180 km NW	N		dry = wet
Wichita Mountains	N	OK17	103 km NE	N		dry = wet
Wolf Island	N	GA09	103 km SW	N		dry = wet

	ESTIMATION OF WET DEPOSITION – NADP			ESTIMATION OF DRY DEPOSITION - CASTNet		
International Class I Areas	On-site monitoring	Cal Code	Comments	On-site monitoring	Site/ID	Comments
Roosevelt-Campobello	N	ME98		N		dry = wet

Distance and direction, when noted, refer to the location of the monitoring site relative to the Class I area.
N/A is not available
NADP data are available at http://nadp.sws.uiuc.edu
CASTNet data for NPS are available from john_ray@nps.gov
CASTNet data for USDA/FS are available at http://www.epa.gov/acidrain/castnet
Wet deposition data at CASTNet site available from frank.neil@epa.gov

E. FUTURE FLAG WORK

1. IMPLEMENTING FLAG RECOMMENDATIONS

FLAG participants believe that the recommendations in this document should be implemented as soon as possible. Therefore, an attempt has been made to present thorough and clear guidance of the processes that will be used to protect and improve AQRVs in FLM areas.

Many of the issues and recommendations discussed herein are complex and require specialized knowledge. Consequently, State agencies and others who intend to use this information in NSR/PSD permitting, land planning and use, and other activities, deserve further guidance and implementation assistance. FLAG members anticipate that much of this guidance and assistance will be provided locally through established formal and informal links between FLMs, States, EPA and others. However, FLAG members also see the need to conduct workshops and training sessions and to provide guidance on the Internet.

2. PHASE I UPDATES

The FLAG Phase I report is intended to clearly state FLM guidance regarding NSR/PSD as it exists in December 2000. As the FLMs learn more about how to better assess the health and status of AQRVs, and as EPA produces new modeling tools, the FLAG guidance will be revised accordingly. As periodic revisions become necessary, any such revisions will be made to the web-based FLAG report. Any revisions to the report will be clearly stated on the FLAG web site. Additionally, once EPA promulgates the New Source Review Reform regulations, the FLMs may need to revise the FLAG Phase I report to address any inconsistencies that may result.

3. PHASE II TASKS

Phase I has addressed issues that could be resolved relatively quickly, without extensive research or the collection of new data. During Phase II, FLAG will address the more complex issues and concerns, including those that may require additional data collection.

In Phase II, to the extent resources permit, FLAG members intend to fill information gaps identified in Phase I, recommend methods for establishing critical loads of pollutants, and attempt to resolve remaining differences in the policies and processes FLMs use to evaluate the effects of pollutants on AQRVs. In Phase II FLAG will also provide additional research and monitoring recommendations.

Other potential Phase II tasks include:

- Refine policies to prevent adverse AQRV impacts, and restore adversely impacted AQRVs.
- Refine procedures for cumulative AQRV impact analyses.
- Promoting internal (FLM) emission reductions through implementation of sustainable practices.
- Recommending a policy on redesignation of Class II federal lands to Class I.
- Clarifying FLM roles and responsibilities on Class II lands.
- Recommending a consistent policy regarding increment tracking and enforcement.

Issue-specific Phase II tasks are discussed in the individual subgroup reports.

APPENDIX A. GLOSSARY

The list below contains definitions for some of the terms used in the *FLAG Phase I Report*. These terms are defined in the sense that they relate to the work of the Federal Land Managers (FLMs) in protecting air resources.

For terms whose definition is lengthy or complex, the associated *Code of Federal Regulations* (CFR) section or other reference is cited.

AIR QUALITY RELATED VALUE (AQRV). A resource, as identified by the FLM for one or more Federal areas, that may be adversely affected by a change in air quality. The resource may include visibility or a specific scenic, cultural, physical, biological, ecological, or recreational resource identified by the FLM for a particular area.

ADVERSE IMPACT ON AN AQRV. An unacceptable effect, as identified by an FLM, that results from current, or would result from predicted, deterioration of air quality in a Federal Class I or Class II area. A determination of unacceptable effect shall be made on a case-by-case basis for each area taking into account existing air quality conditions. It should be based on a demonstration that the current or predicted deterioration of air quality will cause or contribute to a diminishment of the area's national significance, impairment of the structure and functioning of the area's ecosystem, or impairment of the quality of the visitor experience in the area.

ADVERSE IMPACT ON VISIBILITY. Visibility impairment which interferes with the management, protection, preservation, or enjoyment of a visitor's visual experience of a Federal Class I or Class II area. This determination must be made on a case-by-case basis taking into account the geographic extent, intensity, duration, frequency and time of visibility impairments, and how these factors correlate with (1) times of visitor use of the Class I area, and (2) the frequency and timing of natural conditions that reduce visibility. This term does not include effects on integral vistas. [40 CFR §51.301(a)]

ABSORPTION. The process by which incident light is removed from the atmosphere and retained by a particle.

ABSORPTION COEFFICIENT. A number that is proportional to the “amount” of light removed from a sight path by absorption per unit distance.

ACIDIFICATION. The decrease of acid neutralizing capacity in water or base saturation in soil caused by natural or anthropogenic processes.

AEROSOL. A mixture of microscopic solid or liquid particles in a gaseous medium. Smoke, haze, and fog are aerosol examples.

AIRSHED. A geographic area that, because of topography, meteorology, and/or climate, is frequently affected by the same air mass.

AOT40. Sum of all hourly average concentrations after subtracting 40 ppb from each hourly value.

BACT (BEST AVAILABLE CONTROL TECHNOLOGY). The control level (or control measures) required for sources subject to PSD. (See 40 CFR §52.21(b)(12), or 40 CFR §51.166(b)(12)).

CLASS I AREA. As defined in the Clean Air Act, the following areas that were in existence as of August 7, 1977: national parks over 6,000 acres, national wilderness areas and national memorial parks over 5,000 acres, and international parks.

CRITICAL LOAD. The concentration of air pollution above which a specific deleterious effect may occur.

CUMULATIVE EFFECT. The impact on an AQRV resulting from the total pollutant loading from all sources including the contributing effects of known and reasonably foreseeable new and modified sources of air pollution. A single source may cause individually minor, but cumulatively significant, effects on AQRVs.

DAMAGE. Any reduction in the intended use or value of a biological or physical resource. For example, economic production, ecological structure or function, aesthetic value, or biological or genetic diversity that may be altered by a pollutant.

EMISSION OFFSET. A Federally enforceable reduction in emissions from an existing source that mitigates the impacts of a proposed new or modified source on AQRVs, PSD increments, and/or NAAQS. Also, Federally enforceable reductions in actual emissions from existing sources in a nonattainment area such that the total allowable emissions from a new or modified source and existing sources will be sufficiently less than the total emissions from existing sources before the application for a permit to construct so as to represent reasonable further progress towards attainment of the NAAQS. (See 42 U.S.C. § 7503(a)(1)(A))

EXTINCTION. The attenuation of light due to scattering and absorption as it passes through a medium.

FUGITIVE EMISSIONS. Emissions which do not pass through a stack, chimney, vent, or other functionally equivalent opening.

FEDERAL LAND MANAGER (FLM). The Secretary of the Department with authority over such lands. [40 CFR §51.166(b)(24)] The FLM for the Department of the Interior has been delegated to the Assistant Secretary for Fish and Wildlife and Parks; the FLM for the Department of Agriculture has been delegated to the Forest Service, and has been redelegated to the Regional Forester or individual Forest Supervisor.

FLUX. Gaseous uptake into plant tissue.

GREEN LINE. The total pollutant loading (contributions from existing and proposed sources) below which there is a very high degree of certainty that no AQRV will be adversely affected.

HAZE. An atmospheric aerosol of sufficient concentration to be visible. The particles are so small that they cannot be seen individually, but are still effective attenuating light and reducing visual range.

HYDROCARBONS. Compounds containing only hydrogen and carbon. Examples: methane, benzene, and decane.

HYGROSCOPIC. Readily absorbing moisture, as from the atmosphere.

INJURY. Any physical or biological response to pollutants, such as a change in metabolism, reduced photosynthesis, leaf necrosis, premature leaf drop, or chlorosis.

LAER (LOWEST ACHIEVABLE EMISSIONS RATE). The control level required of a source subject to nonattainment review. (See 40 CFR §51.165(a)(1)(xiii))

LIMIT OF ACCEPTABLE CHANGE. The amount of change that could occur without significantly altering an AQRV or sensitive receptor.

MICROMETER. A unit of length equal to one millionth of a meter; the unit of measure for particle size.

MIE THEORY. A complex mathematical mol as a 3sllows; the comluttliot oftThe amount ofzenrgye light) scnateiredby osphetical particlis.

may have, or are having, on the air quality or on the AQRVs of an area. Such monitoring includes both "ambient" monitoring and "AQRV" monitoring and may involve short-term and long-term measurements made at locations representative of the greatest expected impacts.

PSD INCREMENTS. The maximum increases in ambient pollution concentrations allowed over baselines concentrations. See 40 CFR §51.166 (c) for increments for specific pollutants.

RACT (REASONABLY AVAILABLE CONTROL TECHNOLOGY). The lowest emissions limit that a particular source can meet by the application of control technology that is reasonably available considering technological and economic feasibility.

RAYLEIGH SCATTERING. The scattering of light by particles much smaller than the wavelength of the light, *e.g.*, molecular scattering in the natural atmosphere.

RECONSTRUCTED EXTINCTION. Extinction estimate that results from summing up the product of the mass of each measured particle species and the appropriate absorption or extinction coefficient.

RED LINE. The total pollutant loading (contributions from existing and proposed sources) at which there is a very high degree of certainty that at least one AQRV will be adversely affected.

REGIONAL HAZE VISIBILITY IMPAIRMENT. Any humanly perceptible change in visibility (light extinction, visual range, contrast, coloration) from that which would have existed under natural conditions, caused predominantly by a combination of many sources from, and occurring over, a wide geographic area.

RE-OPENER. A permit condition that requires the permitting authority, at a specified time after permit issuance, to review and revise, if necessary, the permit based on new information such as the findings from post-construction monitoring, updated emissions inventories, updated modeling, research, or information on air pollution effects to terrestrial, aquatic, and visibility resources.

SCATTERING. An interaction of a light with an object (*e.g*., a fine particle) that causes the light to be redirected in its path.

SCATTERING COEFFICIENT. Measure of the ability of particles to scatter light; measured in number proportional to the "amount" of light scattered per unit distance.

SCREENING LEVEL OR SCREENING LEVEL VALUE (SLV). The concentration or dose of air pollution below which estimated impacts from a proposed new or modified source are considered insignificant. The SLV is dependent on existing air quality and on the condition of the AQRV of concern.

SENSITIVE RECEPTOR. The AQRV, or part thereof, that is the most responsive to, or the most easily affected by the type of air pollution in question. For example, at Great Smoky Mountains National Park, spruce-fir forest is a sensitive receptor of the AQRV flora.

SENSITIVE RECEPTOR INDICATOR. A measurable physical, chemical, biological, or social (*e.g.*, odor) characteristic of a sensitive receptor. For example, for the sensitive receptor, Crater Lake, water clarity is a sensitive receptor indicator.

STATIONARY SOURCE. A source of pollution that is well defined, such as the smokestack of a coal-fired power plant or smelter.

SULFATES. Those aerosols that have origins in the gas-to-aerosol conversion of sulfur dioxide; of primary interest are sulfuric acid and ammonium sulfate. Sulfuric acid and ammonium sulfate are very hygroscopic so their contribution to visibility impairment is magnified in the presence of water vapor.

SULFUR DIOXIDE. A gas ($S0_2$) consisting of one sulfur and two oxygen atoms. Of interest because sulfur dioxide converts to an aerosol.

SUM00. The sum of all hourly average concentrations above 0 ppb.

SUM06. The sum of all hourly average concentrations at or above 60 ppb.

TARGET LOAD. The acceptable concentration or dose of an air pollutant that provides a reasonable margin of safety below the critical load. The target load should be achievable under existing conditions.

TRANSMISSOMETER. An instrument that measures the amount of light extinction over a fixed, specified path length.

VISIBILITY IMPAIRMENT. Any humanly perceptible change in visibility (visual range, contrast, coloration) from that which would have existed under natural conditions. [40 CFR §51.301(x)]

VISUAL RANGE. The distance at which a large black object would just disappear from view.

VOLATILE ORGANIC COMPOUND (VOC). Any compound of carbon, except those excluded by EPA, that participates in atmospheric photochemical reactions. (See 40 CFR §51.100(s))

W126. An ozone index that multiplies each specific concentration by a sigmoidal weighted function, then sums all values. $W_i = 1/[1 + Me^{-(A \times Ci)}]$, where M and A are constants 4403 and 126 ppm^{-1}, respectively, w_i is the weighting factor for c_i, and c_i is concentration in ppm.

APPENDIX B.

LEGAL FRAMEWORK
FOR MANAGING AIR QUALITY AND AIR QUALITY EFFECTS
ON FEDERAL LANDS

Introduction

The regulation of air pollution sources has clearly been delegated to EPA, and as applicable, the States. However, Federal Land Managers (FLMs) have the responsibility to protect the particular values of the lands over which they have jurisdiction, to the extent they have been delegated the authority, from the adverse impacts of activities inside and outside these areas.

This Appendix sets out the basic legal authorities and responsibilities with which the FLMs comprising FLAG must comply, in addition to those authorities which they can utilize to protect AQRVs on public lands.

For the purposes of this Appendix only, the term "public lands" is defined to include units of the National Park, National Wildlife Refuge, and National Forest Systems.

I. AGENCY ORGANIC ACTS

A. Department of the Interior: National Park Service (NPS):

This Organic Act is very specific in that it mandates national park unit managers:

[T]o conserve the scenery and the natural and historic objects and wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.

16 U.S.C. §1(1997); and

> [T]he authorization of activities shall be construed and the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided for by Congress.
>
> 16 U.S.C. § 1a-1 (1997)

B. Department of the Interior: Fish and Wildlife Service (FWS):

With respect to National Wildlife Refuge System lands (Refuge System lands under the jurisdiction of the United States Fish and Wildlife Service (FWS), FWS managers are required to manage Refuge System lands so to:

[E]nsure that the biological integrity, diversity, and environmental health of the System are maintained for the benefit of present and future generations of Americans.

16 U.S.C. §668dd(a)(4)(B)(1997)

C. Department of Agriculture: Forest Service (Forest Service)

National Forest System lands are defined as:

[A]ll National Forests reserved or withdrawn from the public domain of the United States, all national forests acquired through purchase, exchange, donation, or other means, all national grasslands and land utilization projects...and all lands waters, and other interests administered by the Forest Service.

16 U.S.C. §1609(a)(1997)

The Forest Service's Organic Administration Act of 1897 directs the Secretary of Agriculture to:

[M]ake provisions for the protection against destruction by fire and depredations upon the public forests and national forests...

16 Sec. §551(1997)

The National Forest units are managed consistent with Land and Resource Management Plans (LRMPs) under the provisions of the National Forest Management Act (NFMA). 16 §U.S.C. 1604 (1997). Any measures addressing AQRVs on National Forest System lands will be implemented through, and be consistent with, the provisions of an applicable LRMP or its revision (16 U.S.C. §1604(i)).

The Secretary of Agriculture is required by law to prepare a Renewable Resource Assessment by 1979, and every 10 years thereafter. By law this Assessment is required to address:

3. A description of Forest Service programs in research, cooperative programs and management of the National Forest System, their relationships, and the relationships of these programs and responsibilities to public and private activities; and

5. An analysis of the potential effects of global climate change on the condition of renewable resources on the Forests and rangelands of the United States; and

6. An analysis of the rural and urban forestry opportunities to mitigate the buildup of atmospheric carbon dioxide and reduce the risk of global climate change.

16 U.S.C. §1601(a) (1997)

In addition, the Secretary of Agriculture is required to prepare and transmit to the President, a Renewable Resource Program (the Program) every 5 years. This Program must include program recommendations which recognize the fundamental need to protect, and where appropriate, improve the quality of ... air resources. 16 U.S.C. §1602(5)(C).

The Forest Service's implementing regulations for NFMA are found at 36 C.F.R. §219 et seq. LRMPs are, in part, specifically based on:

[R]ecognition that the National Forests are ecosystems and their management for goods and services requires an awareness and consideration of the interrelationships among plants, animals, soil, water, air, and other environmental factors within such ecosystems.

36 C.F.R. §219.1(b)(3)

II. The Wilderness Act. 16 U.S.C. §1131 (1997).

AQRVs in Wilderness areas may receive further protection by the language of the Wilderness Act itself which states:

Wilderness areas... shall be administered for the use of the American people in such a manner as will leave them unimpaired for future use and enjoyment as wilderness .... (16 U.S.C. Sec. §1131).

For Wilderness Areas in the National Forest System, the Act's implementing regulations are found at 36 C.F.R. §293. These Wilderness Areas shall be administered:

...[For] such other purposes for which it may have been established in such a manner as to preserve and protect [their] wilderness character. In carrying out such purposes, National Forest Wilderness resources shall be managed to promote, perpetuate, and, where necessary, restore the wilderness character of the land...

36 C.F.R. §293.2 (1997)

III. The Clean Air Act, 42 U.S.C. §7401 et seq.

Because of a perceived need for national and regional air quality research to support State programs, Congress passed its first federal air quality initiative in 1955. (Air Pollution Control Act of 1955, ch. 360, 69 Stat. 322). In response to increasing harm to public health and welfare and to inadequate controls and enforcement, Congress has slowly but steadily expanded and refined the law, now known as the Clean Air Act (CAA), to cover more types of pollutants and emitters; *e.g.*, stationary and mobile sources of pollution. These efforts have culminated in the 1990 Amendments to the CAA, which represent the most comprehensive and detailed set of measures to date to both prevent and curtail air pollution.

The declaration of purpose, as revised in 1990 states in part:

The purposes of this subchapter are: to protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population.

42 U.S.C. § 7401(b)(1); and

A primary goal of this Act is to encourage or otherwise promote reasonable Federal, State, and local government actions, consistent with the provisions of this Act, for pollution prevention.

42 U.S.C. §7401(c)

The CAA provides an additional legal framework for FLMs to preserve and protect AQRVs from pollution sources emanating both within and outside National Park, Forest, and Refuge boundaries.

A. **National Ambient Air Quality Standards (NAAQS) and State Implementation Plans (SIPs):** The CAA establishes a regulatory program with the goal of achieving and maintaining "national ambient air quality standards" (NAAQS) through state or, if necessary, federal implementation plans (SIPs or FIPs).[1]

The U.S. Environmental Protection Agency (EPA) is charged with promulgating:

1. "primary" NAAQS for "criteria" pollutants "to protect the public health," allowing an adequate margin of safety;" and

2. "secondary" NAAQS "to protect the public welfare from any known or anticipated adverse effects associated with the presence of such air pollutant in the ambient air."[2]

The above secondary standards may help protect public land AQRVs.[3] To date, EPA has promulgated NAAQS for six criteria pollutants: sulfur dioxide, particulate matter, nitrogen dioxide, carbon monoxide, ozone and lead. In July of 1997, EPA issued revised, and more stringent NAAQS for ozone and "fine particulate matter" to address human health concerns. However, EPA openly acknowledged that these revised NAAQS were not fully adequate to protect the above "secondary" values, in particular those sensitive AQRVs on public lands.

B. Prevention of Significant Deterioration (PSD):

The CAA, as amended in 1977, includes the following major purposes regarding the "prevention of significant deterioration" (PSD) provisions:

[T]o protect public health and welfare from any actual or potential adverse effect . . . from air pollution . . . notwithstanding attainment and maintenance of all national ambient air quality standards.

42 U.S.C. § 7470(1)

[T]o preserve, protect, and enhance the air quality in national parks, national wilderness areas, national monuments, national seashores, and other areas of special national or regional natural, recreational, scenic, or historic value.

42 U.S.C. §7470(2)

The PSD section provides some protection for park and wilderness AQRVs through establishment of ceilings on additional amounts of air pollution over baseline levels in clean air areas (increments). It requires EPA or the State to provide to the FLM notice of any proposed major emitting facility[4] whose emissions may affect a Class I area (42 U.S.C. §7475(d)(2)(A), and also by charging:

[T]he Federal Land Manager [1] and the Federal official charged with direct responsibility for management of such lands with "an affirmative responsibility to protect the air quality related values (including visibility) of any such lands within a class I area and to consider, in consultation with the Administrator, whether a proposed major emitting facility will have an adverse impact on such values.

42 U.S.C. §7475(d)(2)(B).

Class I areas include national parks larger than 6,000 acres and national wilderness areas and national memorial parks which exceed 5,000 acres, in existence on August 7, 1977. The 1990 Amendments provided that subsequent additions to the boundaries of such areas are also Class I areas. Currently, 48 areas in the National Park system, 21 Refuge System units, and 88 areas under the administration of the Forest Service are designated as Class I.

Under the PSD provisions and implementing regulations (40 C.F.R. §51.166(p)), for Class I areas, once baseline concentrations come under review by submission of a PSD preconstruction permit application for a major new or modified emissions source, only the smallest increment of certain pollutants -- sulfur dioxide, nitrogen oxide and particulate matter -- may be added to the air by the proposed new source, and other "increment consuming" sources.

Under the PSD provisions a FLM has several tools he/she may use to protect AQRVs.

A state may not issue a PSD permit to allow construction or modification of a major emitting facility when the applicable Federal Land Manager files a notice alleging the facility may cause or contribute to a change in the Class I area's air quality and by identifying the potential adverse impact of such a change, unless:

The facility owner demonstrates that the facility's emissions of particulate matter, sulfur dioxide, and nitrogen oxides will not cause or contribute to concentrations which will exceed the maximum allowable increases for that Class I area.

42 U.S.C. §7475(d)(2)(C)(i)(paraphrased) and 42 U.S.C. §7476.

Even if no increment violation is predicted,

[T]he state may not issue a PSD permit, if the Federal Land Manager demonstrates to the satisfaction of the State that the emissions from such facility will have an adverse impact on the air quality-related values (including visibility) of Class I lands.

42 U.S.C. §7475(d)(2)(C)(ii)(paraphrased)

Neither the CAA nor the implementing regulations specify criteria for the FLM to "satisfy" state permitting agencies. Consequently, some states have taken a liberal view of their discretion to reject an FLM's adverse impact determination. However, EPA's Environmental Appeals Board (the Board) has ruled that state discretion in rejecting a FLM's finding of adverse impacts is not "unfettered" (see the Board's decisions regarding the permit appeals for the Old Dominion Electric Cooperative and Hadson Power projects in Virginia). Nevertheless, the appropriate role of the FLM in the PSD permit process is currently being addressed in EPA's proposed New Source Review Reform regulations. The final regulations are expected to be promulgated in 2001.

C. Visibility Protection. Subpart II, 42 U.S.C. §7491 et seq. (1997)

The Visibility portion of the CAA:

"... [D]eclares as a national goal the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory class I Federal areas which impairment results from manmade air pollution."

42 U.S.C. §7491(a)(1).

To help carry out this goal, the Secretaries of the Interior and Agriculture are charged with identifying Class I areas where visibility is an important value. EPA is charged with reporting to Congress on methods to implement the national goal and with promulgating regulations to ensure reasonable progress toward meeting the goal.

In 1980, EPA issued enforceable regulations for visibility impairment "reasonably attributable" to a specific source or small group of sources. In particular, major stationary sources emitting any pollutant which may "reasonably be anticipated to cause or contribute to any impairment of visibility" is required to install best available retrofit technology (BART). In addition, in April 1999 EPA promulgated final regulations addressing regional haze. The regional haze rule protects air quality in Class I areas by requiring States to plan to achieve "natural" visibility conditions over a 60-year timeframe.

The 1990 Amendments add a new section on visibility, which authorizes EPA in conjunction with NPS and other federal agencies, to conduct visibility research and to evaluate clean air corridors and emissions sources and source regions causing visibility impairment in Class I areas. In this regard, EPA was required to establish the Grand Canyon Visibility Transport Commission (GCVTC) by 1991 and consider the recommendations GCVTC would make (42 U.S.C. §7492(f). NPS, FS, FWS, and BLM played a vital role in the work of the GCVTC and committees in an effort to improve air quality in the Grand Canyon and other parks and wilderness areas in the "Golden Circle" on the Colorado Plateau.

As part of the visibility protection process, states are required to promulgate a plan to prevent any future, and remedy any existing impairment of visibility in Class I areas... 40 C.F.R. §51.300 (1997). EPA has defined "visibility impairment" as:

[A]ny humanly perceptible change in visibility (visual range, contrast, coloration) from that which would have existed under natural conditions.

40 C.F.R. §51.301(x)(1997).7

However, EPA has promulgated its visibility regulations to allow FLMs to use their existing authorities to address "visibility impairment" (rather than "significant impairment") so that "the affected Federal Land Manager may certify to the State, at any time, that there exists impairment of visibility in any mandatory Class I Federal area." 40 C.F.R. §51.302(c).

D. Nonattainment Areas, 42 U.S.C. §7501 et seq.:

Areas that have failed to meet NAAQS for one or more criteria pollutants are designated as "nonattainment" areas. Under the 1990 Amendments, Congress provides for further classification of nonattainment areas based on severity of the nonattainment and availability and feasibility of appropriate pollution control measures and for a compliance schedule ranging from 1993 in marginal nonattainment areas to 2010 for Los Angeles.

The 1990 Amendments authorize EPA to issue control technique guidance documents (CTGs) covering a variety of topics, such as control of idling vehicles and voluntary removal of pre-1980 model year light duty vehicles (cash for clunker programs). (42 U.S.C. §7408.) EPA is authorized to issue CTGs, in lieu of regulations, to reduce "volatile organic compounds" (VOC) emissions from any consumer or commercial product. (42 U.S.C. §7511b.)

Proposed new or modified major stationary sources within nonattainment areas are required to meet emissions limits based on "lowest achievable emission reduction" technology (LAER) and may be constructed only if their emissions are sufficiently offset by reductions in emissions from other sources. The 1990 Amendments also require analysis of alternative sites, sizes, production processes, and control techniques and a finding that the benefits of the source outweigh its environmental and social costs. (42 U.S.C. §7501-15.)

E. General

CAA Subchapter III 42 U.S.C. §7601 et seq. contains definitions, requirements for reports to Congress, authorizations for appropriations, and procedures for EPA rulemaking and judicial review. Citizen suits are authorized: 1) against EPA for failure to perform a nondiscretionary duty under the CAA, or 2) against others for alleged violations of an emission limitation, standard, or order. (42 U.S.C.§7601 et seq.)

F. Acid Deposition

The 1990 Amendments add Title IV, which contains requirements for electric utilities to reduce emissions associated with acid rain. To reduce the adverse effects of acid deposition, Title IV requires a reduction in annual emissions of sulfur dioxide of ten million tons from 1980 emission levels and a reduction of nitrogen oxides emissions of approximately two million tons from 1980 emission levels, in the 48 contiguous states and the District of Columbia. (42 U.S.C. §7651.) The Title creates a system of market-based emission allowances, which can be traded among sources. See (42 U.S.C. §7651a-o.)

G. Operating Permits

The 1990 Amendments add Subchapter V, 42 U.S.C. §7661 et seq., which establishes a nation-wide permit program for existing stationary sources. Permit requirements will include emission limitations. EPA may veto state permits, which do not comply with provisions of the CAA. (42 U.S.C. §7661a-f.)

H. Conformity, 42 U.S.C. §7506 (1997)

(Paraphrased) No federal agency may engage in, support in any way,... license or permit, or otherwise approve any activity which does not conform to an approved state (or federal) implementation plan. Conformity shall be an affirmative responsibility of the head of each agency. Conformity means:

(A) Conforming to the SIP's purpose of eliminating or reducing the number of NAAQS violations;

(B) That any such activities will not:

(i) Cause or contribute to new violations in any area; or

(ii) Increase the frequency or severity of any existing standard violation...

EPA, in its "criteria and procedures" for implementing "conformity" has decided that only those activities that "a federal agency can practicably control, and will maintain control over due to a continuing program responsibility" are subject to same. 40 C.F.R. §93.152.

Although required to comply with the conformity provisions (42 U.S.C. §7618(1997)), the FLM cannot use these provisions to protect AQRVs from adverse impacts from offsite sources.

IV. IMPACT ON FEDERAL LAND MANAGERS

The CAA reinforces the FLMs' Organic Act and Wilderness Act roles as protectors of AQRVs on public lands.

The CAA also imposes on FLMs an obligation to comply with the Act's many provisions regarding the abatement of air pollution to the same extent as any private person (42 U.S.C. §7418).

Thus, under various authorities, FLMs are responsible for protecting AQRVs within their respective unit boundaries and taking appropriate action to do so, when reviewing emission sources both within units, and in proximity to unit boundaries.

FLMs, under the CAA, have an affirmative responsibility for protecting AQRVs (including visibility) in reviewing proposed PSD permits. However, because of the uncertainty involved in "satisfying" State permitting agencies in the PSD process, and the appropriate delegated role for FLMs in non-PSD situations, the existing framework may provide an inadequate means for FLMs the conformity provisions (42 U.S.C.cies in uq05o7n uired theo aN FEDERAL LAND MANAGERS

References

1) Clean Air Act, 42 U.S.C. §7401-7671q (as amended 1990).
2) *Clean Air Deskbook*, The Environmental Law Reporter, Environmental Law Institute, 1992.
3) *Managing National Park System Resources: A Handbook on Legal Duties, Opportunities, and Tools*, Chap. 4 "The Clean Air Act" by Molly Ross at pp. 51-65, The Conservation Foundation, 1990.
4) *Atmospheric Environment* Vol. 27B, No. 1, "The 20-Year History of the Evolution of Air Pollution Control Legislation in the U.S.A." by Richard H. Schulze at pp. 15-25.
5) Wilderness Act of 1964, 16 U.S.C. §1131 et seq, P.L. 577, 78 stat 890 as amended.
6) *The Principal Laws Relating to Forest Service Activities*, USDA - Forest Service ISBN 0-16-041927-1, 1993
7) Organic Administration Act of 1897, 16 U.S.C. §473-475, §477-482, §551.

APPENDIX C.

GENERAL POLICY FOR MANAGING AIR QUALITY RELATED VALUES IN CLASS I AREAS

Most Federal Land Manager (FLM) enabling legislation and regulations developed to implement Federal Laws do not directly address air quality, or air pollution effects on Parks or Wildernesses. They do, however, provide broad direction on what should be protected in Parks and Wildernesses (the earth and its community of life) and to what degree (preserve natural conditions or conserve resources unimpaired). Accordingly, FLMs have developed the following policies related to air quality and Class I areas:

1. Class I areas are not merely a commodity for human use and consumption. Park and Wilderness ecosystems have intrinsic values other than user/public concerns.

2. A principle objective of FLM management is to offer a natural user experience, rather than strictly an enjoyable one. The amount of enjoyment is purely a personal matter for the individual user to decide.

3. All Class I components are equally important; none is of lesser value than another.

4. A Class I component is important even if users of the area are unaware of its existence.

5. All life forms are equally important. For example, microorganisms are as essential as elk, wild flowers, or grizzly bears.

6. The goal of Class I management is to protect not only resources with immediate aesthetic appeal (*i.e.*, sparkling clean streams) but also unseen ecological processes (such as natural biodiversity and gene pools).

7. The most sensitive Class I components are to be emphasized more than those of "average" or "normal" sensitivity. Sensitivity is generally determined by inertia (resistance to change), elasticity (how far the component can be stretched from its natural condition without being permanently modified), and resiliency (the number of times it can revert to its natural condition after experiencing human-caused change).

8. Each Class I component is important in itself; as well as in terms of how it interacts with other components of the ecosystem. That is, the individual parts of the Class I ecosystem are as significant as the sum of the parts.

9. The physical components of the ecosystem (for instance, lake chemistry) are as essential as its biological constituents (*i.e.*, salamanders). That is, the earth is as essential as the community of life.

10. Class I components are to be protected from "human-caused change" rather than from "damage." Terms such as "damage" and "harm" are prejudicial, whereas "human-caused change" is value-neutral. (For example, deposits of nitrogen in a lake from nitrogen oxide, a common air pollutant, might result in more plant growth and larger fish. This would, however, be an unnatural - and therefore unacceptable - change in the aquatic ecosystem).

11. The goal of Class I management is to protect natural conditions, rather than the conditions when first monitored. That is, if initial monitoring in a Class I area identifies human-caused changes, appropriate actions should be taken to remedy them, in order to move towards a more natural condition.

12. The designation of a Park or Wilderness as Class I or II does not dictate the management goals for it; these are identified in the enabling legislation. The designation only determines which options are available to meet the goals. Class I Parks or Wildernesses, for instance, can be protected through AQRV analysis, whereas the protection of Class II Parks and Wildernesses can be achieved Tc nBACTto quiragemeson.

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APPENDIX D.
BEST AVAILABLE CONTROL TECHNOLOGY (BACT) ANALYSIS

Given the need to minimize emissions and their resulting air quality impacts, the FLMs recommend that the applicant conduct the BACT analysis using EPA’s top-down approach. In brief, a top-down process ranks all available control technologies in descending order of control effectiveness. All of the available control systems for the source, including the most stringent, must be considered. The applicant first examines the most effective, or top, alternative. That alternative is established as the BACT unless the applicant demonstrates, and the permitting authority agrees, that technical considerations, or energy, environmental, or economic impacts justify a conclusion that the most stringent technology is not achievable in that case. FLMs utilize EPA’s BACT/RACT/LAER Clearinghouse, and other information, for assessing control technologies proposed by permit applicants.

If the most stringent technology is eliminated in this fashion, then the next most stringent alternative is considered, and so on. Permit applicants should refer to chapter B of the *EPA New Source Review Workshop Manual* for a detailed discussion of the top-down policy.

The FLM reviews the applicant's BACT analysis to determine if the best available pollution control technology is being proposed, thereby minimizing the proposed emission increases and their corresponding impact on the FLM area in question. The FLM does this by comparing the proposed controls to recent BACT determinations for similar facilities. If the FLM disagrees with the applicant's BACT analysis, technical comments are submitted to the permitting authority who has the ultimate responsibility to make the BACT determination and issue the permit.

The environmental impacts analysis of the BACT review is not to be confused with the air quality-related analysis. The environmental impacts analysis of the BACT review should concentrate on impacts other than ambient air quality impacts of the regulated pollutant in question, such as solid or hazardous waste generation, discharges of polluted water from a control device, or emissions of unregulated pollutants. Thus, the fact that a given control alternative would result in only a slight improvement in ambient concentrations of the pollutant in question when compared with a less stringent control alternative, should not be viewed as a basis for rejecting the more stringent control alternative.

Regarding the economic impact analysis, given the special protection Class I areas are afforded under the Clean Air Act, FLMs believe that the need to minimize potential impacts on a Class I area should be a major consideration in the BACT determination for a project proposed near such an area. Therefore, if a source proposes to locate near a Class I area, additional costs to minimize impacts on sensitive Class I resources may be warranted, even though such costs may be considered economically unjustified under other circumstances.

APPENDIX E. MAPS OF FEDERAL CLASS I AREAS

APPENDIX F. CLASS I AREA CONTACTS

USDA FOREST SERVICE CLASS I AREAS

REGION 1

Class I Areas:

Anaconda-Pintler Wilderness
Bob Marshall Wilderness
Cabinet Mountains Wilderness
Gates of the Mountains Wilderness
Mission Mountains Wilderness
Scapegoat Wilderness
Selway-Bitterroot Wilderness

Contact: Ann Acheson
Phone Number: (406) 329-3493
Fax Number: (406) 329-3132
Email Address: aacheson@fs.fed.us
Mailing Address:
USDA Forest Service, Region 1
P.O. Box 7669
Missoula, MT 59807

REGION 2

Class I Areas:

Eagles Nest Wilderness
Fitzpatrick Wilderness
Flat Tops Wilderness
La Garita Wilderness
Maroon Bells - Snowmass Wilderness
Mount Zirkel Wilderness
North Absaroka Wilderness
Rawah Wilderness
Washakie Wilderness
Weminuche Wilderness
West Elk Wilderness

Contact: Dennis Haddow
Phone Number: (303) 275-5759
Fax Number: (303) 275-5754
Email Address: dhaddow@fs.fed.us
Mailing Address:
USDA Forest Service, Region 2
P.O. Box 25127
Lakewood, CO 80225-0127

REGION 3

Class I Areas:

Chiricahua Wilderness
Galiuro Wilderness
Gila Wilderness
Mazatzal Wilderness
Mount Baldy Wilderness
Pecos Wilderness
Pine Mountain Wilderness
San Pedro Parks Wilderness
Sierra Ancha Wilderness
Superstition Wilderness
Sycamore Canyon Wilderness
Wheeler Peak Wilderness
White Mountain Wilderness

Contact: Debby Potter, Ph.D.
Phone Number: (505) 842-3143
Fax Number: (505) 842-3800
Email Address: dapotter@fs.fed.us
Mailing Address:
USDA Forest Service, Southwestern Region
Federal Building
517 Gold Ave., S.W.
Albuquerque, NM 87102

REGION 4

Class I Areas:

Bridger Wilderness
Hells Canyon Wilderness*
Hoover Wilderness
Jarbidge Wilderness
Sawtooth Wilderness*
Teton Wilderness

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Fax Number: (303) 275-5754
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USDA Forest Service, Region 2
P.O. Box 25127
Lakewood, CO 80225-0127

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Email Address: aacheson@fs.fed.us
Mailing Address:
USDA Forest Service, Region 1
P.O. Box 7669
Missoula, MT 59807

REGION 5

Class I Areas:

Caribou Wilderness
Marble Mountain Wilderness
South Warner Wilderness
Thousand Lakes Wilderness
Yolla Bolly - Middle Eel Wilderness

Contact: Suraj Ahuja
Phone Number: (916) 934-5630
Fax Number: (916) 934-7384
Email Address: sahuja@fs.fed.us
Mailing Address:
Mendocino National Forest
420 E. Laurel Street
Willows, CA 95988

Class I Areas:

Agua Tibia Wilderness
Cucamonga Wilderness
San Gabriel Wilderness
San Gorgonio Wilderness
San Jacinto Wilderness
San Rafael Wilderness
Ventana Wilderness

Contact: Mike McCorison
Phone Number: (818) 574-5286
Fax Number: (818) 574-5233
Email Address: mmccorison@fs.fed.us
Mailing Address:
Angeles National Forest
701 N. Santa Anita Ave.
Arcadia, CA 91006

Class I Areas:

Ansel Adams Wilderness
Desolation Wilderness
Dome Land Wilderness
Emigrant Wilderness
John Muir Wilderness
Kaiser Wilderness
Mokelumne Wilderness

Contact: Trent Procter

Phone Number: (559) 784 -1500, ext. 1114
Fax Number: (559) 781 - 4744
Email Address: tprocter@fs.fed.us
Mailing Address:
Sequoia National Forest
900 W. Grand Ave.
Porterville, CA 93257-2035

REGION 6

Class I Areas:

Alpine Lakes Wilderness
Diamond Peak Wilderness
Eagle Cap Wilderness
Gearhart Mountain Wilderness
Glacier Peak Wilderness
Goat Rocks Wilderness
Hells Canyon Wilderness
Kalmiopsis Wilderness
Mt. Adams Wilderness
Mt. Hood Wilderness
Mt. Jefferson Wilderness
Mt. Washington Wilderness
Mountain Lakes Wilderness
Pasayten Wilderness
Strawberry Mountain Wilderness
Three Sisters Wilderness

Contact: Bob Bachman

Phone Number: (503) 808 - 2918
Fax Number: (503) 808 - 2973
Email Address: rbachman@fs.fed.us
Mailing Address:
USDA Forest Service, Region 6
P.O. Box 3623
Portland, OR 97208-3623

REGION 8

Class I Areas:
Dolly Sods Wilderness
James River Face Wilderness
Otter Creek Wilderness

Contact: Cindy Huber
Phone Number: (540) 265-5156
Fax Number: (540) 265-5145
Email Address: chuber@fs.fed.us
Mailing Address:
Jefferson National Forest
5162 Valleypointe Parkway
Roanoke, VA 24019

Class I Areas:
Joyce Kilmer - Slickrock Wilderness
Linville Gorge Wilderness
Shining Rock Wilderness

Contact: Bill Jackson
Phone Number: (704) 257-4815
Fax Number: (704) 257-4263
Email Address: bjackson02@fs.fed.us
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National Forests in North Carolina
P.O. Box 2750
Asheville, NC 28802

Class I Areas:
Caney Creek Wilderness
Upper Buffalo Wilderness

Contact: Laura Hudnell
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Email Address: lhudnell@fs.fed.us
Mailing Address:
Ouachita National Forest
Box 1270, Federal Building
Hot Springs Natl. Park, AR 71902

Class I Areas:
Bradwell Bay Wilderness
Cohutta Wilderness
Sipsey Wilderness

Contact: Dave Wergowske
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Email Address: dwergowske@fs.fed.us
Mailing Address:
National Forests in Alabama
2946 Chestnut Street
Montgomery, AL 36107-3010

REGION 9

Class I Area:
Boundary Waters Canoe Area

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Fax Number: (218) 720-5600
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Superior National Forest
Box 338, Federal Building
515 W. First St.
Duluth, MN 55802

Class I Area:
Lye Brook Wilderness

Contact: Nancy Burt
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Fax Number: (802) 747-6766
Email Address: nburt@fs.fed.us
Mailing Address:
Green Mountain National Forest
231 N. Main Street
Rutland, VT 05701

Class I Areas:
Great Gulf Wilderness
Presidential Range - Dry River Wilderness

Contact: Joan Carlson
Phone Number: (603) 528-8721
Fax Number: (603) 528-8783
Email Address: jcarlson@fs.fed.us
Mailing Address:
White Mountain National Forest
719 Main Street
Laconia, NH 03246-0772

Class I Area:
Hercules - Glades Wilderness

Contact: Laura Hudnell
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Fax Number: (501) 321-5353
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Mark Twain National Forest
401 Fairgrounds Road
Rolla, MO 65401

Class I Area:
Rainbow Lakes Wilderness

Contact: Dale Higgins
Phone Number: (715) 762-5181
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Chequamegon National Forest
1170 4th Avenue South
Park Falls, WI 54552

NATIONAL PARK SERVICE CLASS I AREAS

For inquiries regarding routine permit issues, contact the NPS Air Resources Division in Lakewood, Colorado: John Bunyak, Chief, Policy, Planning and Permit Review Branch; (303) 969-2818; john_bunyak@nps.gov; P.O. Box 25287, Denver CO, 80225.

ALASKA REGION

Denali National Park and Preserve
Contact: Andrea Blakesley
Phone Number: (907) 683-2294
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P.O. Box 9
Denali Park, AK 99755

INTERMOUNTAIN REGION

Arches National Park
Contact: Superintendent
Phone Number: (801) 259-3911
Fax Number: (801) 259-8341
Mailing Address:
P.O. Box 907
Moab, UT 84532

Bandelier National Monument
Contact: Superintendent
Phone Number: (505) 672-3861
Fax Number: (505) 672-9607
Mailing Address:
HCR 1, Box 1, Suite 15
Los Alamos, NM 87544

Big Bend National Park
Contact: Superintendent
Phone Number: (915) 477-2251
Fax Number: (915) 477-2357
Mailing Address:
P.O. Box 129
Big Bend National Park, TX 79834

Black Canyon of the Gunnison National Park
Contact: Superintendent
Phone Number: (970) 641-2337
Fax Number: (970) 641-2337
Mailing Address:
P.O. Box 1648
Montrose, CO 81402

Bryce Canyon National Park
Contact: Superintendent
Phone Number: (435) 834-5322
Fax Number: (435) 834-4102
Mailing Address:
P.O. Box 170001
Bryce Canyon, UT 84717

Canyonlands National Park
Contact: Superintendent
Phone Number: (801) 259-3911
Fax Number: (801) 259-8628
Mailing Address:
P.O. Box 907
Moab, UT 84532

Capitol Reef National Park
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Phone Number: (801) 425-3791
Fax Number: (801) 425-3026
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Torry, UT 84775

Carlsbad Caverns National Park
Contact: Superintendent
Phone Number: (505) 785-2232
Fax Number: (505) 785-2133
Mailing Address:
3225 National Parks Highway
Carlsbad, NM 88220

Chiricahua National Monument
Contact: Superintendent
Phone Number: (520) 824-3560
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Willcox, AZ 85643

Glacier National Park
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Grand Canyon National Park
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Grand Canyon, AZ 86023

Grand Teton National Park
Contact: Superintendent
Phone Number: (307) 739-3300
Fax Number: (307) 739-3438
Mailing Address:
P.O. Box 170
Moose, WY 83012

Great Sand Dunes National Monument
Contact: Superintendent
Phone Number: (719) 378-2312
Fax Number: (719) 378-2594
Mailing Address:
11500 Highway 150
Mosca, CO 81146

Guadalupe Mountains National Park
Contact: Superintendent
Phone Number: (915) 828-3251
Fax Number: (915) 828-3269
Mailing Address:
HC 60, Box 400
Salt Flat, TX 79847-9400

Mesa Verde National Park
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Rocky Mountain National Park
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Estes Park, CO 80517

Saguaro National Park
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3693 South Old Spanish Trail
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Yellowstone National Park
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Yellowstone National Park, WY 82190

Zion National Park
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Springdale, UT 84767

MIDWEST REGION

Badlands National Park
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Isle Royale National Park
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87 North Ripley Street
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Theodore Roosevelt National Park
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Voyageurs National Park
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International Falls, MN 56649

Wind Cave National Park
Contact: Dan Roddy
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Hot Springs, SD 57747

NORTHEAST REGION

Acadia National Park
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Bar Harbor, ME 04609

Shenandoah National Park
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Fax Number: (540) 999-3601
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Mailing Address:
3655 U.S. Highway 211 East
Luray, VA 22835

PACIFIC WEST REGION

Crater Lake National Park
Contact: Superintendent
Phone Number: (541) 594-2211
Fax Number: (541) 584-2299
Mailing Address:
P.O. Box 7
Crater Lake, OR 97604

Craters of the Moon National Monument
Contact: Superintendent
Phone Number: (208) 527-3257
Fax Number: (208) 527-3073
Mailing Address:
P.O. Box 29
Arco, ID 83213

Haleakala National Park
Contact: Superintendent
Phone Number: (808) 572-9306
Fax Number: (808) 572-1304
Mailing Address:
P.O. Box 369
Makawao, HI 96768

Hawaii Volcanoes National Park
Contact: Superintendent
Phone Number: (808) 985-6025
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Volcanoes, HI 96718

Joshua Tree National Park
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Kings Canyon National Park
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47050 Generals Highway
Three Rivers, CA 93271

Lassen Volcanic National Park
Contact: Superintendent
Phone Number: (530) 595-4444
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P.O. Box 100
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Lava Beds National Monument
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Point Reyes National Seashore
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Point Reyes, CA 94956

Redwood National Park
Contact: Superintendent
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Yosemite National Park
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SOUTHEAST REGION

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Great Smoky Mountains National Park
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St. Thomas, VI 00802

U.S. FISH AND WILDLIFE SERVICE CLASS I AREAS

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Bosque Del Apache Wilderness

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Salt Creek Wilderness

Contact: Refuge Manager

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Wichita Mountains Wilderness

Contact: Refuge Manager

Phone Number: (580) 429-3007
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Seney Wilderness

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Seney NWR
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Seney, MI 49883

Mingo Wilderness

Contact: Refuge Manager

Phone Number: (573) 222-3589
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REGION 4

Breton Wilderness

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Cape Romain Wilderness

Contact: Refuge Manager

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Fax Number: (803) 928-3803
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Cape Romain NWR
5801 Highway 17 North
Awendaw, SC 29429

Chassahowitzka Wilderness

Contact: Refuge Manager

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Chassahowitzka NWR
1502 S. Kings Bay Drive
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Okefenokee Wilderness
Contact: Refuge Manager
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Folkston, GA 31537

St. Marks Wilderness
Contact: Refuge Manager
Phone Number: (850) 925-6121
Fax Number: (850) 925-6930
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St. Marks NWR
P.O. Box 68
St. Marks, FL 32355

Swanquarter Wilderness
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Phone Number: (252) 926-4021
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Mattamuskeet NWR
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Swanquarter, NC 27885

Wolf Island Wilderness
Contact: Refuge Manager
Phone Number: (912) 652-4415
Fax Number: (912) 652-4385
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Savannah Coastal Refuges
1000 Business Center Dr., Ste. 10
Savannah, GA 31405

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Brigantine Wilderness
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Moosehorn Wilderness
Contact: Refuge Manager
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Baring, ME 04694-9703

REGION 6

Lostwood Wilderness
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Kenmare, ND 58746-9046

Medicine Lake Wilderness
Contact: Refuge Manager
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Medicine Lake NWR
223 North Shore Road
Medicine Lake, MT 59247

Red Rock Lakes Wilderness
Contact: Refuge Manager
Phone Number: (406) 276-3536
Fax Number: (406) 276-3538
Mailing Address:
Red Rock Lakes NWR
Monida Star Route, Box 15
Lima, MT 59739

UL Bend Wilderness
Contact: Refuge Manager
Phone Number: (406) 538-8706
Fax Number: (406) 538-7521
Mailing Address:
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Lewistown, MT 59457

REGION 7

Bering Sea/Simeonof/Tuxedni Wilderness Areas

Contact: Refuge Manager

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APPENDIX G. FLAG PARTICIPANTS

The individuals listed in the attached table participated in the development of the *FLAG Phase I Report*. The abbreviations for the FLAG subgroup or committee on which participants served are shown below.

LC = Leadership Committee
CC = Coordinating Committee
P = Policy Subgroup
V = Visibility Subgroup
O = Ozone Subgroup
D = Deposition Subgroup
T = Terminology (Glossary) Subgroup

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APPENDIX H. BIBLIOGRAPHY

Some of the documents cited below were referenced in this *FLAG Phase I Report.* Others are listed to provide background information.

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